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**BAYER LEVERKUSEN (GERMANY)**

Department for Crop Protection

## Efforts to introduce late blight controls between the Weser and the Ems, and difficulties involved

by P. Blaszyk, Aurich

Late blight occurs regularly in regions where there is heavy and frequent rainfall in summer, and where the temperatures are high enough to stimulate the development of *Phytophthora infestans* de By. As a result, considerable yield losses are suffered, and the quality of the harvested crop is greatly reduced. It is amazing that farmers often take such little advantage, even in areas affected by severe late blight epidemics, of the possibility that has existed for so long to reduce the losses caused by this disease, by repeatedly treating the crops with fungicides. One of the reasons for this is that many farmers do not fully realise how serious the damage is, and furthermore it is difficult to convince them of the necessity to carry out regular controls of late blight. The obvious course, therefore, would be to demonstrate, by means of examples, the economy of this practice in order to gradually win over reticent farmers.

The Crop Protection Office at Oldenburg — the entire area administered by this office suffers heavy losses year after year as the result of late blight incidence — in fact took up this idea some considerable time ago and, in close cooperation with the Regional Crop Protection Study Group set up by the industry, has established over the past six years 310 demonstration late blight control sites distributed throughout the Weser-Ems region. These sites were concentrated each year in 2 to 6 districts, as far as possible alongside roads; they were correspondingly signed. The number of sites treated each year is given in Table 1.

No particular varieties were selected for the treatments. Rathermore, the model controls were laid on in fields of favourable location. In keeping with cultivation conditions, far more middle-late and late varieties such as "Heida", "Voran", "Maritta" and "Ackersegen" were treated than such middle-early varieties as "Cornelia", "Fina" and the highly susceptible "Bona"; the demonstrations included practically no earlies at all. Special emphasis was laid on carrying out the treatments in keeping with agricultural practice, in other words by using tractor-mounted and tractor-drawn sprayers; in some cases, use was also made of horse-drawn sprayers. The work was done by spraying contractors who carried out the treatments, in the presence of a crop protection technician, on dates laid down by the Crop Protection Office. Each site was treated three times. A section measuring 300 square metres was left untreated in all the demonstration sites which mostly had an area of more than 1 hectare. As soon as the untreated plots had become severely infected, arrangements



were made for them to be inspected by various organisations; invitations were sent to farmers, agricultural advisory centres, spraying contractors, trade associations, broadcasting corporations and the press. This provided an opportunity not only to demonstrate the outstanding differences in leaf infection between treated and untreated plots but also to compare harvest results for middle-early varieties (Fig. 1). Unfortunately, few farmers usually attended, probably because these inspections always took place at a time when the farmers were very busy.

All sites were evaluated with four replications with respect to yield. The starch content and the percentages of tubers infected by brown rot were also determined. Table 1 gives the yield increases obtained for the different years, which — as shown in the last column of this table — are very favourably expressed in the increased financial returns. It is notable that the yield increase was most appreciable in all the six years, and in fact amounted to more than 25 % in four of these years. The increased value of the yield can actually be estimated even higher because on the average worked out for all years the sprayed potatoes had a starch content which was about 1 % greater than that of the unsprayed potatoes; this naturally makes a considerable difference in the case of industrial processing or pig fattening. A significant decrease of brown rot infection was not established, however; this cannot really be expected when only three treatments are carried out which merely delay leaf infection but cannot prevent it.

Table 1: Results of demonstration late blight controls 1953—1958

| Year           | No. of demonstration sites | No. of varieties | Average yield increases |    | Financial yield** increase |
|----------------|----------------------------|------------------|-------------------------|----|----------------------------|
|                |                            |                  | dz*/ha                  | %  |                            |
| 1953           | 30                         | 5                | 71                      | 33 | 539                        |
| 1954           | 55                         | 17               | 43                      | 15 | 287                        |
| 1955           | 71                         | 13               | 71                      | 30 | 539                        |
| 1956           | 54                         | 17               | 46                      | 16 | 314                        |
| 1957           | 57                         | 21               | 68                      | 26 | 512                        |
| 1958           | 43                         | 26               | 59                      | 25 | 431                        |
| 6 year average |                            |                  | 59.7                    | 24 | 437                        |

\* dz = Doppelzentner (100 kilos)

\*\* Spraying costs deducted (these are estimated at DM 100 for 3 spray applications). Potatoes priced at DM 9 per 100 kilos.

The importance of the late blight control does not become fully apparent to the calculating farmer, however, until consideration is given to the influence of yield losses on the net receipts (Table 2). The net receipts which drop more rapidly than the gross proceeds, can be completely nullified as the result of relatively slight yield losses. The tabulated figures show, inter alia, that at a selling price for potatoes of DM 9 per 100 kilos (Doppelzentner), a farm which does not protect its potato crop against late blight and which realises an average yield of barely 22 500 kilos per hectare, operates practically without net receipts under these conditions; on the other hand, if it were to carry out

effective late blight controls, and the harvest yield is increased by 25 %, net receipts of DM 430 are realised. When lower prices are paid for potatoes, it will naturally always be more difficult to realise a profit when appreciable losses are suffered due to late blight incidence; at a potato price of DM 8 per 100 kilos, and even with a harvest yield that is above average amounting to 25 000 kilos per hectare, no profit at all will be realised when late blight controls are not carried out. In the event of even lower prices being quoted, it would require an expert farmer who, however, sprays his potatoes, to realise a modest net profit.



Fig. 1: (Left: Untreated, yield from 200 plants; 20,800 kilos per hectare. Right: Sprayed 3 times, yield from 200 plants; 30,100 kilos per hectare.)

A most noteworthy fact is that yield losses which are equally high on percentage, reduce profits far more in intensive than in extensive cultivation. However, under the economic conditions existing at present, potatoes can be grown only as an intensive culture in most agricultural establishments. For this reason, prevention of yield losses by such diseases as late blight attaches far greater importance under present-day conditions than in former times when cultivation was practised on more extensive lines.

From the economy aspect, the prevention of high losses due to late blight incidence, which in our area averaged 24 % over 6 years in 310 fields (approx.



22 % in more than 700 tests carried out in North-Rhine/Westphalia), is of particular interest in that acreage can be correspondingly limited, which means that the farmer gains new land free of charge on which he can grow other crops. The high value attached to reduction of losses by means of crop protection practices along with improvement of quality — in face of the present threat of overproduction in agriculture and market gardening — is often not so much a case of bringing about an absolute increase of harvest yields but rathermore to produce equally high yields on smaller areas at less expenditure.

Table 2: Change in net profit for a yield increase of 25 % brought about by 3 late blight sprays.

Total expenditure = DM 2000/ha — Spraying costs = DM 100/ha

| Potato price in DM/dz* | untr. 200 dz/ha | tr. 250 dz/ha | untr. 225 dz/ha | tr. 281 dz/ha | untr. 250 dz/ha | tr. 314 dz/ha | untr. 275 dz/ha        | tr. 344 dz/ha |                        |
|------------------------|-----------------|---------------|-----------------|---------------|-----------------|---------------|------------------------|---------------|------------------------|
| 7                      | — 600           | — 350         | — 425           | — 130         | — 250           | 80            | — 75                   | 300           | } net profits in DM/ha |
| 8                      | — 400           | — 100         | — 200           | 150           | 0               | 400           | 200                    | 650           |                        |
| 9                      | — 200           | 150           | 25              | 430           | 250             | 700           | 475                    | 1000          |                        |
| Potato price in DM/dz* | untr. 300 dz/ha | tr. 375 dz/ha | untr. 325 dz/ha | tr. 406 dz/ha | untr. 350 dz/ha | tr. 438 dz/ha |                        |               |                        |
| 9                      | 700             | 1275          | 925             | 1550          | 1150            | 1840          | } net profits in DM/ha |               |                        |
| 8                      | 400             | 900           | 600             | 1150          | 800             | 1400          |                        |               |                        |
| 7                      | 100             | 525           | 275             | 750           | 450             | 970           |                        |               |                        |

\* dz = Doppelzentner (100 kilos)

untr. = untreated

tr. = treated

One ought to assume that the results of the numerous demonstration controls carried out in the past six years would have completely convinced farmers of the necessity of controlling late blight especially as very great pains were taken to make this widely known by demonstrations, radio broadcasts, articles in trade journals and daily newspapers, lectures and individual consultations. Apart from a few limited districts where intensive seed potato production is practised, the degree of success achieved cannot by any means be regarded as satisfactory, however, because the majority of farmers continue as before to resign themselves to the regular high losses caused by late blight without doing anything to remedy the situation. There are various reasons for this:

1. Although the results obtained at the demonstration sites were known to most farmers in the Weser-Ems region, they could not be instilled upon them with sufficient emphasis in the relatively short time available because the Crop Protection and Industrial Advisory Organizations did not have enough personnel for this task. Organizations concerned with advising

farmers on matters of general management should make it their task to cooperate intensively with the other competent bodies in ensuring that the practice of late blight control, as one of the most economic measures for increasing the profitableness of potato cultivation, is adopted on all farms and that it becomes an integral part of the routine programme regarded as being just as essential as, say, fertilization.

2. The profitableness of potato growing will naturally be reflected all the more in the overall success of farming practice, the greater the percentage of the total effective acreage that is used for cultivating potatoes. Farms which have a big potato acreage will be generally far more interested in keeping losses caused by late blight at as low a level as possible. In many districts between the Weser and the Ems, potatoes are grown on only a moderate scale.
3. Great difficulties are experienced in exploiting the most favourable times for spraying due to very many rainy days in July and August. This especially applies to the first preventive treatment. Under these conditions, and in view of the limited efficiency of the available spraying equipment, a prognosis of *Phytophthora* with the object of giving warnings at short notice — as in fruit farming and viticulture, for example — would only be of little value.
4. Many farmers have gone over to the practice of engaging contractors to carry out spray applications instead of doing it themselves. As a result, approximately 65 % of all spraying operations were carried out by contractors last year in the Weser-Ems regions. But many of these contractors are not very interested in carrying out late blight controls because
  - a) they often need their machines at this time for other work which is more profitable,
  - b) the unsettled weather makes it impossible to go ahead with the work at a steady rate, which is so important if contract spraying is to be a profitable undertaking,
  - c) the work is also made less economical due to the small size of the plots (less than 1 hectare) in many cases, and because the plots are so scattered,
  - d) varieties that ripen and are planted at different times cannot always be treated on the same date,
  - e) the varied spacing between rows in the different fields makes it practically impossible to use a big machine,
  - f) there are too few spraying days in order to be able to carry out promptly the required number of spray applications for all customers with the equipment available.

The difficulties that oppose the general introduction of late blight controls are, therefore, unusually great in an area which has very much rainfall in summer, especially when potato cultivation, as in the Weser-Ems regions, is practised on most farms on a scale that seriously affects the overall success of the business when severe losses are suffered, although not completely ruining it. It is essential that all advisory organisations, and not only the crop protection organisation, make every endeavour to persuade farmers that annual losses brought about by late blight have a very unfavourable influence on the



overall turnover, and not until this is done will there be a gradual and firm desire among farmers to avoid such losses despite all difficulties. A condition for success is the employment of a sensible cultivation technique, in particular uniform spacing between rows, cultivation in relatively large plots, and the provision of an adequate scale of equipment. Farm-owned and community-owned equipment will prove very valuable for carrying out controls promptly. Spraying contractors will be forced, for economic reasons, to limit their work to the treatment of the bigger cultivated areas or to increase the costs for the treatment of small plots.

## On the Control of Late Blight in Switzerland

by P. Moilliet and G. Müller

### A. Extent of crop protection in potato growing

In Switzerland, the control of late blight holds first place among crop protection practices in algriculture. A relatively favourable price is paid for table and fodder potatoes, thus giving certain encouragement to take extensive measures, although there are other factors of much greater bearing — the serious danger of infection that is prevalent every year and the constantly rising production costs. When expenditure in the region of 3500 to 4000 francs has to be incurred per hectare for the cultivation and care of a crop, it is obvious that every calculating farmer will risk a further 200 to 400 francs to safeguard such a big investment. If he does not, then his investment will be in danger because there has surely never been a year when this devastating disease has not been known to occur. It can, therefore, be asserted that the control of late blight has developed into an indispensable crop protection practice throughout the entire growing region, which deserves our full attention.

In the main growing regions of Central Switzerland, the first infections usually break out already in late May and early June. The danger of latent infections continues almost every year until well into August. Controls are started at the end of May and early June. More treatments follow at intervals of 8 to 20 days so that a spraying programme that has included in recent years 4 to 5 or even 6 treatments is not exceptional in many regions but rathermore constitutes a standard practice. This applies especially to the Bintje variety which is chiefly grown; although very susceptible, this variety is still in great demand among consumers because of its quality.

### B. Products applied

In addition to Bordeaux mixtures which, however, are applied today on an ever-decreasing scale, greater use was being made until recently of 50 % oxychlorides. But during the past two years, there has also been a large demand for 35 % copper hydroxide-calcium chlorides (CUPRAVIT® Blue etc.) which

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have rapidly become popular due to their excellent effect. The dosages of pure copper applied per hectare vary between 2.5 to 5 kg, the standard rate being 3 to 4 kg.

Organic products have so far been used only on a small scale. Widespread skepticism as to adequate residual effect and the production of increased yields — in fact these have often not been established or if so then only to a very slight degree — justifiably seems to present a hindrance to expansive application.

### **C. Burning of tops**

Burning of tops in seed potato production is a compulsory measure laid down by the Swiss Agricultural Research Stations. As soon as the danger arises of virus diseases being spread by aphids, farmers and growers are notified of the final date by which the tops must be destroyed. In recent years this date fell between July 20 and 25. The methods are also specified. First of all, the tops have to be thoroughly damaged by means of some suitable appliance, for example a Cambridge roller, a hay-pole with barbed wire wound around it, a harvester chopper or a special type of weed cutter. Then they must be sprayed. So far DNOC products have been the only preparations to give the effect required by the regulations. DNOC (containing 40 %  $\text{NH}_4$  salt as active substance) is applied at a rate of 30 to 40 kg in 2000 to 2400 l of water per hectare; the field of damaged tops is treated twice.

Burning of tops is also becoming a widespread practice in fields of table and fodder potatoes. Here, however, it is not usual to break up the tops first; the dosage varies between 20 to 25 kg of DNOC dissolved in 1500 litres of water per hectare. The reason for the introduction of this hygienic practice in table and fodder potato production may be attributed to the fact that hereby the spread of late blight is immediately suppressed before the tubers can become infected, furthermore the speedy and thorough removal of tops and weeds facilitates the use of modern harvesting machinery, a factor which today especially attaches increasing importance because of the growing shortage of labour and rising wages.

### **D. Spraying programme**

In view of what has already been stated, crop protection practices in potato growing can be generally outlined as follows:

#### **1. Seed potatoes**

2 to 3 spray applications of a copper product between the end of May and early July.

Destroying and burning of tops to prevent spread of virus infections, to be completed by about July 20.

#### **2. Table potatoes (Bintje variety)**

3 to 6 sprays carried out from the end of May to August.

If necessary, burning of tops to reduce tuber infections and to facilitate harvesting.

3. Table potatoes (less susceptible varieties)  
and fodder potatoes  
2 to 3 spray applications.  
If necessary, burning of tops.

### E. Example

To illustrate what has been said above, the authors would like discuss a test carried out in 1958 by Agrochemie A. G. at Bern.

1. Problem set: a) Comparison of the effect of 3 copper products and 1 copper-zineb preparation on *Phytophthora infestans*.  
b) Is it worthwhile to control late blight?
2. Test products and dosages.

Table 1:

| Product                     | Active substance                      | Conc.<br>in % | kg active<br>substance*<br>per hectare<br>(for 100 l<br>of solution/ha) |
|-----------------------------|---------------------------------------|---------------|-------------------------------------------------------------------------|
| CUPRAVIT Blue "Bayer"       | Copper hydroxide-<br>calcium chloride | 0.8—1.0       | 2.8—3.5 (Cu)                                                            |
| Copper product X            | Copper oxychloride                    | 0.5—0.8       | 2.5—4.0 (Cu)                                                            |
| "Bayer" 4848                | Copper oxychloride                    | 0.5—0.8       | 2.5—4.0 (Cu)                                                            |
| LONACOL®-<br>Copper "Bayer" | Zineb-Copper                          | 0.5—0.6       | { 1.75—2.1 kg Cu +<br>1.0 —1.2 kg Zineb                                 |

\* The larger dosage was applied only in the last treatment.

### 3. Test conditions

Location: Niederruntigen Kt. Bern

a) 510 metres below s. l., flat

b) Deep sandy loam, pH = 7

c) Bintje variety

d) State of growth at start of test on June 6, 58

Height: approx 40 cm; plants beginning to close up and touch in the rows.

e) Size of test plots: 20 sq. m.

5 replications

Spraying equipment: Knapsack sprayer

Rate of application: 1000 litres of solution/ha

Dates of treatment: June 6, 13, 25, July 2, 9, 1958

Burning of tops: August 6, 1958

Harvest: September 29, 1958

Arrangement: randomized blocs



## Methods of evaluation:

### a) Evaluation of leaf infection:

Following the appearance of the first disease symptoms, the development of infection on the leaves was recorded by means of counts. 20 stems of equal thickness were sampled in each plot. Counts were taken on each sampled stem of the following:

- all leaves
- all completely infected leaves
- all infected partial leaves.

As the leaves of the Bintje variety were made up of 7 partial leaves, the number of infected partial leaves was divided by 7, and the result was added to the total of infected leaves.

Example: 20 stems consist of a total of 256 leaves.

Of these, 131 are 100 % infected (all partial leaves dead).

Also counted: 147 infected partial leaves.

$$\frac{147}{7} = 21 \text{ whole leaves.}$$

No. of leaves infected out of 256 on 20 stems:

$$131 + 21 = 152 \text{ leaves or } 59.4 \%$$

### b) Evaluation of yield:

The width of the plots extended over 5 furrows (3.35 metres), with a length of 6 metres. At the harvest on September 29, 1958, the three centre furrows in each plot were dug up by hand over a length of 5 metres. The tubers yielded were weighed immediately after they had been dug up.

## 4. Procedure of the test

The procedure of the test is shown by means of a graph given in Fig. 1. Measureable data included:

minimum temperature measured daily at the test site; relative humidity measured several kilometres away from the test field — daily minima entered in Fig. 1;

rainfall in mm, entered as daily totals.

According to Beaumont et al., an infection can occur when a minimum relative humidity (measured at a meteorological station) of 75 % and a minimum temperature of 10°C are recorded during a period of 48 hours. These conditions prevailed in our test on the following dates:

10.—11. 6. 58 (temperature only just reached)

20.—21. 6. 58

24.—26. 6. 58 (close)

Our observations showed that the first disease symptoms appeared on July 1, 1958, which indicates that there was still no outbreak of infection on June 10—11, whereas an infection did occur on June 20—21. The infection curve for the untreated plots (in Fig. 1 the average values of infection are entered for 5 plots) rises very sharply in the first half of July, indicating that the outbreak of infection on June 20—21 was rather severe. It is also

assumed from the increased infection in July that the disease again spread on June 24—26, 1958 although the conditions specified by Beaumont did not prevail at that time. This inconsistency may be attributed to the fact that we were forced to measure the relative humidity at a point several kilometres away from the actual test field.

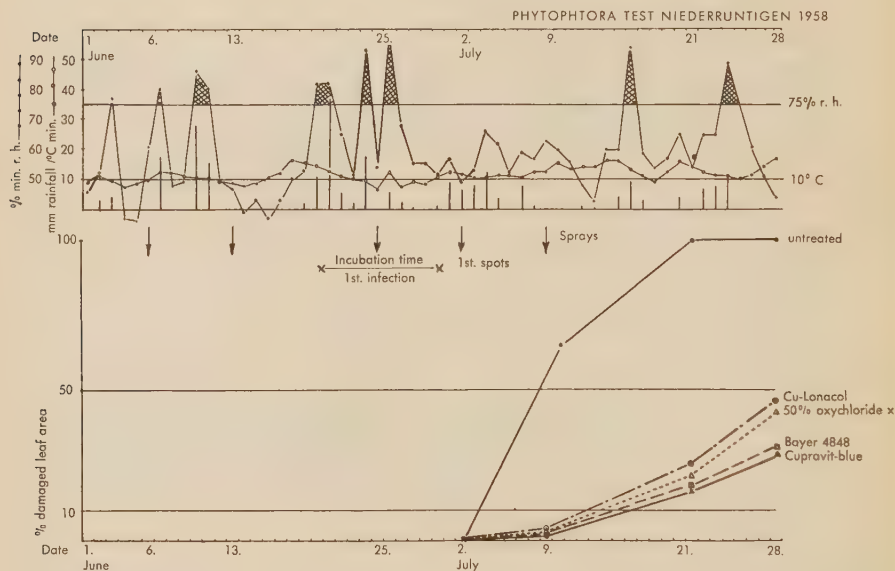


Fig. 1: Weather conditions, spraying times and leaf infection

## 5. Result

### a) Leaf infection

The practical conclusion which we wish to draw from the test is that 5 spray applications succeeded in suppressing leaf infection in the untreated plots for a period of 4 weeks following the outbreak of the disease, thus guaranteeing a full crop. The value of the first treatment on June 6, 1958 may be disputed because it was carried out some considerable time before the first infection. It must, however, be borne in mind that the possibility of infections breaking out cannot be forecast with certainty, added to which it is often difficult to drive a sprayer over a field at the time specified after infection has broken out. Furthermore, we know from experience that it is a very valuable practice to spray the crop before the tops close up because as a result of such treatment the stems and oldest leaves which later are not easy to wet, are provided with a certain protective reserve of copper.

It is found that there are essential differences among the products used. The longer the counts are delayed following the last treatment (on July 9,



1958), the more persistent are CUPRAVIT Blue and "Bayer 4848", whereas the effect of copper oxychloride X and LONACOL-Copper lessens progressively. The reason for the rapid decrease in the effect of the last-mentioned product may be attributed to the considerably smaller dosage of copper per hectare (see Table 1).

On the other hand, it may be concluded from the facts given that the formulation of a product has just as much bearing on this as the dosage of copper (compare "4848" and oxychloride X).

#### b) Yields

Table 2 gives the yields converted to Doppelzentner (100 kg) per hectare (square metre/ha).

It is at once noticed that irrespective of the product used, a yield increase of approximately 10,000 kg and more was obtained as a result of the spray applications. On the other hand, the differences among the various products used are not significant. The combined product LONACOL-Copper did not bring about a yield increase despite its 20 % content of zineb.

Table 2: Yield of healthy tubers in Doppelzentner (100 kg) per hectare.

| Product        | Conc. %  | Replications |       |       |       |       | Average yield | Yield increase in % |
|----------------|----------|--------------|-------|-------|-------|-------|---------------|---------------------|
|                |          | I            | II    | III   | IV    | V     |               |                     |
| CUPRAVIT Blue  | 0.8—1.0* | 362.5        | 387.1 | 394.6 | 322.9 | 337.9 | 361.0         | 40.7                |
| 50 % oxychl. X | 0.5—0.8  | 377.5        | 361.4 | 385.0 | 335.8 | 324.0 | 356.7         | 39.0                |
| "Bayer 4848"   | 0.5—0.8  | 378.8        | 368.9 | 362.5 | 386.0 | 378.6 | 374.9         | 46.1                |
| LONACOL-Cu     | 0.5—0.6  | 389.3        | 393.5 | 364.7 | 326.2 | 336.8 | 362.1         | 41.1                |
| Untreated      | —        | 239.5        | 291.9 | 238.5 | 245.9 | 267.3 | 256.6         | —                   |

\* only in last (5th) treatment.

#### c) Economy

We have calculated the expenses for the standard product CUPRAVIT Blue incurred in our test to give an adequate control of late blight, and have compared them with the profits. With respect to these calculations, it should be mentioned that the price of 3 francs quoted for the application of 100 litres of spray wash is rather high. On the other hand, the division of the harvest yield into 60 % table potatoes and 40 % fodder potatoes may be regarded as a modest calculation. Usually the sorting results are more favourable, which also applies to the average price per 100 kg. The prices given correspond to the producer's prices ex farm paid in Autumn, 1958.

Average yield increase with CUPRAVIT Blue 104400 kg/ha Bintje

Additional expenditure:

a) Control of late blight:

4 × 1000 l of spray wash 0.8 % = 32 kg of CUPRAVIT Blue

1 × 1000 l of spray wash 1.0 % = 10 kg of CUPRAVIT Blue

Total 42 kg of CUPRAVIT Blue

= Fr. 141.12

Wages (for spraying) 50 hl à Fr. 3.—

= Fr. 150.—

Total for late blight control

= Fr. 291.12

b) Burning of tops:

1 × 1500 l of spray wash 1.5 % = 22.5 kg of DNOC "Bayer" Fr. 45.—

Wages (for spraying) 15 hl à Fr. 3.—

Fr. 45.—

Fr. 91.25

Total for burning of tops

Fr. 136.25

Total additional expenditure

Fr. 427.37

Average potato price,

assuming 60 % of harvest is table potatoes à Fr. 23.— per 100 kg

40 % of harvest is fodder potatoes à Fr. 10.— per 100 kg

Average price Fr. 17.80 per 100 kg

2400 kg of potatoes are needed to cover the costs of the control.

Profit for 10440 kg yield increase as compared with untreated

= Fr. 1431.— per hectare

Relations for lower prices and smaller yield increases

| Average<br>potato price<br>per 100 kg | Yield (expressed in<br>100 kg) of potatoes<br>needed to cover<br>costs of spraying<br>(Fr. 427.37) | Profit realised expressed in<br>Fr. . . . per hectare for a yield increase of: |         |         |         |
|---------------------------------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|---------|---------|---------|
|                                       |                                                                                                    | 10000 kg                                                                       | 8000 kg | 6000 kg | 4000 kg |
| 17.80                                 | 24.0                                                                                               | 1352.8                                                                         | 996.8   | 664.8   | 284.8   |
| 17.—                                  | 25.1                                                                                               | 1273.3                                                                         | 933.3   | 593.3   | 253.3   |
| 16.—                                  | 26.7                                                                                               | 1172.8                                                                         | 852.8   | 532.8   | 212.8   |
| 15.—                                  | 28.5                                                                                               | 1072.8                                                                         | 772.8   | 472.5   | 172.5   |
| 14.—                                  | 30.5                                                                                               | 973.0                                                                          | 693.0   | 413.0   | 133.0   |
| 13.—                                  | 32.9                                                                                               | 872.3                                                                          | 612.3   | 352.3   | 93.3    |
| 12.—                                  | 35.6                                                                                               | 772.8                                                                          | 532.8   | 292.8   | 52.8    |
| 11.—                                  | 38.9                                                                                               | 672.1                                                                          | 452.1   | 232.1   | 12.1    |
| 10.—                                  | 42.7                                                                                               | 573.0                                                                          | 373.0   | 173.0   | —       |

The high costs incurred for the control in 1958 due to the very severe incidence of late blight, were more than offset as a result of the price paid. The effective profits do not include the protection given against tuber infections in storage. Although only healthy tubers were picked in the untreated plots and weighed at the late harvest on September 29, 1958, it is nevertheless assumed that a part of the abundant spore material which spread in July settled in the soil around the tubers as a latent source of infection.

## F. Summary

- a) The control of late blight is one of the most important agricultural crop protection practices in Switzerland.
- b) In view of the danger of infection that prevails each year, the high production costs and the relatively favourable prices paid for crops, it is essential that the potato fields are given extensive protection.
- c) Copper products are still in greatest demand. Products with 35 % of the CUPRAVIT Blue type have proved to be most effective and have become firmly established since they were introduced in 1956.
- d) Burning of tops is a practice that is being adopted on an ever-widening scale; it makes for healthier crops and is labour-saving.  
In seed potato production areas, burning of tops with DNOC is a compulsory measure introduced for the prevention of virus propagation.
- e) The general facts outlined in this paper are confirmed by the results of a test carried out in 1958, which show that good copper products are superior to the copper-zinc product which was used; in this respect, it should be pointed out that appreciable differences of effect exist among the copper products that were applied.
- f) The relatively high costs incurred for the control operations were far more than offset. In fact a most considerable profit of approximately Fr. 1400—per hectare was realised.

## Trial controls of late blight in Rheinland-Pfalz, 1950—1958

by A. Niemöller, Regional Crop Protection Office, Mainz

In 1950, the Regional Crop Protection Office of Rheinland-Pfalz, in conjunction with its branch offices, started a series of demonstration controls of late blight and exact spraying tests, which extended over a period of several years. The conditions for infection and propagation by *Phytophthora* vary most appreciably in Rheinland-Pfalz. Rainfall averaging 450 to 550 mm is recorded in the Vorderpfalz and Rheinhessen districts where the soil is primarily of the alluvial type; in Pfälzer Wald, Hunsrück, Eifel and Westerwald, potatoes are grown at heights of up to 500 metres, and the mean rainfall here is between 800 and 900 mm. There is a great amount of ground fog in the deep valleys of the Rhine, Nahe, Moselle and Lahn and their tributaries. Consequently there is a constant change of favourable and unfavourable conditions for the propagation of the fungus in Rheinland-Pfalz. The valleys of the Rhine, Moselle, Nahe, Lahn and Ahr rivers, and the Eifel, Hunsrück, Westerwald, Pfälzer Wald and Kaiserslauterer Valley constitute areas that are especially susceptible to *Phytophthora* incidence.



In 1950, evaluations of 98 tests showed yield increases amounting to 4800 kilos per hectare or 20 %.

A yield increase of 4700 kg/ha or 20 % was obtained in 79 tests  
with one treatment each  
" " " 5700 kg/ha or 22 % was recorded in 13 tests  
each incorporating two treatments  
" " " 3100 kg/ha or 16 % was obtained in 6 tests  
with three treatments each.

The following excess profits were realised at a price of DM 10.— per 100 kg of potatoes, material costs of approx. DM 17.— per hectare (single treatment) and labour costs of DM 10.— per hectare (single treatment):

|                       |            |
|-----------------------|------------|
| for one treatment     | + DM 443.— |
| for two treatments    | + DM 516.— |
| for three treatments  | + DM 239.— |
| average excess profit | + DM 399.— |

In 1951, evaluations of 282 tests showed a yield increase of 4500 kg/ha or 17 %.

In 69 tests with one treatment each, a yield increase of  
4400 kg/ha or 17 % was obtained  
In 185 tests with two treatments each, a yield increase of  
4600 kg/ha or 15 % was obtained  
In 28 tests with three treatments each, a yield increase of  
4400 kg/ha or 25 % was obtained

The following excess profits were realised at the same prices (costs) as above:

|                       |            |
|-----------------------|------------|
| for one treatment     | + DM 413.— |
| for two treatments    | + DM 406.— |
| for three treatments  | + DM 359.— |
| average excess profit | + DM 400.— |

A series of exact tests was conducted in 1953 especially in the area covered by the Crop Protection Branch Office at Koblenz. As in the previous years, these tests were again arranged and evaluated by the crop protection technicians attached to the agricultural colleges. The results of the 1953 tests are given according to the college districts, together with the names of the treated varieties. This latter information provides an interesting survey of the susceptibility of the varieties, a factor that was also studied in each case. On the average, two treatments were carried out with the following results:

| College district of Polch | yield increases | yield increases |
|---------------------------|-----------------|-----------------|
|                           | in dz*/ha       | in %            |
| 5 tests Bona variety      | 84.6            | 63.0            |
| 5 tests Heida variety     | 92.4            | 43.5            |
| 1 test Forelle variety    | 158.0           | 68.7            |
| 2 tests Sabina variety    | 172.0           | 83.9            |
| 1 test Ackersegen variety | 92.0            | 39.5            |
| 1 test Sieglinde variety  | 10.0            | 8.8             |

\* dz = Doppelzentner (100 kilos)

|                                               | yield increases<br>in dz*/ha | yield increases<br>in % |
|-----------------------------------------------|------------------------------|-------------------------|
| College district of Niederbieber              |                              |                         |
| 2 tests Bona variety                          | 62.5                         | 71.5                    |
| 4 tests Heida variety                         | 143.7                        | 59.4                    |
| 4 tests Toni variety                          | 97.5                         | 42.9                    |
| 1 test Olympia variety                        | 85.0                         | 39.5                    |
| College district of Lutzerath                 |                              |                         |
| 7 tests Heida variety                         | 96.1                         | 26.3                    |
| 2 tests Olympia variety                       | 55.0                         | 14.4                    |
| College district of Kaisersesch               |                              |                         |
| 1 test Heida variety                          | 250.0                        | 104.5                   |
| 2 tests Olympia variety                       | 50.0                         | 24.0                    |
| 1 test Böhms Mittelfrühe variety              | 50.0                         | 18.5                    |
| College district of Emmelshausen              |                              |                         |
| 11 tests Bona variety                         | 88.6                         | 38.1                    |
| 11 tests Heida variety                        | 58.6                         | 23.0                    |
| 1 test Böhms Mittelfrühe variety              | 72.0                         | 41.5                    |
| College district of St. Goarshausen/Nastätten |                              |                         |
| 2 tests Bona variety                          | 69.0                         | 41.8                    |
| 5 tests Heida variety                         | 86.1                         | 46.7                    |
| 6 tests Ackersegen variety                    | 76.2                         | 35.3                    |
| 1 test Voran variety                          | 28.0                         | 15.9                    |
| College district of Hachenburg/Westerburg     |                              |                         |
| 3 tests Bona variety                          | 86.4                         | 34.0                    |
| 2 tests Heida variety                         | 63.5                         | 27.8                    |
| 6 tests Ackersegen variety                    | 54.7                         | 21.9                    |
| 3 tests Lerche variety                        | 60.7                         | 33.0                    |

The following numbers of tests were evaluated according to varieties:

|                                   |       |      |
|-----------------------------------|-------|------|
| 23 tests Bona variety             | 83.4  | 46.2 |
| 35 tests Heida variety            | 90.3  | 36.7 |
| 13 tests Ackersegen variety       | 67.5  | 29.4 |
| 5 tests Olympia variety           | 59.0  | 23.3 |
| 4 tests Toni variety              | 97.5  | 42.9 |
| 2 tests Böhms Mittelfrühe variety | 61.0  | 30.0 |
| 1 test Voran variety              | 28.0  | 15.9 |
| 2 tests Sabina variety            | 17.0  | 83.9 |
| 1 test Sieglinde variety          | 10.0  | 8.8  |
| 3 tests Lerche variety            | 60.7  | 33.0 |
| 1 test Forelle variety            | 158.0 | 68.7 |
| 90 tests 11 varieties             | 80.6  | 38.0 |

The following excess profits were realised at the same prices as above:

|                                   |          |
|-----------------------------------|----------|
| Increased receipts per hectare    | DM 806.— |
| Costs for spray and miscellaneous | DM 54.—  |
| Net profit                        | DM 752.— |

\* dz = Doppelzentner (100 kilos)

In 1955, the evaluated results obtained in the previous year were made known at lectures and courses, in articles and at consultations with farmers. Demonstration controls of late blight were again carried out everywhere as an additional publicity measure. Progressive farmers soon followed the advice of the official Crop Protection Organization, although many continued to display a hesitating attitude towards the controls.

The agricultural colleges and their advisory offices assisted the Crop Protection Organization in its efforts everywhere. In the following years the crop protection technicians carried out more exact tests; details and results of these were published in the annual reports of the agricultural colleges, and communicated at lectures and agricultural meetings.

In the years 1956—1958, the following results were obtained in exact trial controls of late blight carried out in Rheinland-Pfalz (these tests each incorporated three spray applications):

| Yield increase in dz(100 kg)/ha |          | Yield increase in % |
|---------------------------------|----------|---------------------|
| 1956                            | 54 tests | 73.6                |
| 1957                            | 26 tests | 29.6                |
| 1958                            | 22 tests | 69.9                |
|                                 |          | 31.2                |
|                                 |          | 11.5                |
|                                 |          | 24.7                |

The susceptibility of the varieties was also studied in the tests. Erstlinge, Sieglinde, Bona, Flora, Sabina, Heida and Böhm's Mittelfrühe were found to be very susceptible.

Moderately susceptible varieties included Olympia, Vera and Maritta, while Ackersegen, Voran, Merkur and Aquilla were only slightly infected.

In all the tests carried out it was established that especially in areas threatened by *Phytophthora* infection, copper sprays (copper oxychloride 45—50 %)\* were superior to white sprays in economy and effect, and gave the plants most effective protection against *Phytophthora* fungus. The dosage of the copper products should not exceed 4 to 5 kg/ha because it was found that higher dosages did not give yield increases. The products were applied at volumes of 400 litres and 600 litres per hectare, the 600 litre volume being more effective. Smaller dosages and lower volumes than those specified above do not guarantee successful control.

Farmers have always objected that dense potato crops are damaged by mobile spraying equipment to such an extent that late blight controls will not produce increased yields, but this was not confirmed in any of the tests. In fact this finding is of very great importance when stressing upon farmers the necessity of late blight controls.

It will take some time before the farmers follow the advice of the Crop Protection Office and cooperate with this organization. No doubt many years will elapse before the farmers come to accept crop protection, and are fully convinced of its inestimable value and absolute necessity. It is extremely essential that information is provided regularly in radio broadcasts, in the press and at

\* e. g. CUPRAVIT® (Ob 21)

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lectures, and by means of warnings of infection issued by the Crop Protection Organization. The control of late blight is an ideal example of how successfully crop protection practices can be carried out, and it is an easy matter for every economically minded farmer to work out for himself the advantages offered by proper implementation of such measures. There is no other investment in agriculture which brings in such good returns as late blight controls in such a short time and with such high interest.

## On the use of FOLIDOL® Oil for bud-burst spraying

by Eugen Bender, Crop Protection Field Station, Meersburg (Lake Constance)

We conducted studies extending from 1949 to 1952, on the effect of various winter sprays on overwintering pests. The observations were carried out each spring on pome and stone fruit trees in the Lake Constance region; both our own trial sprayings and also winter sprayings in plantations not treated by us, were checked. During the winter season, before winter spraying was started, we sampled pieces of branches of a certain length in these plantations, and examined them in the laboratory for overwintering pests (eggs and larvae). Furthermore, samples of branches, leaf and flower clusters were taken in spring after budding from treated and untreated trees, and checked for live pests.

In parallel tests, winter spraying was omitted, and the overwintering pests were controlled by using the new insecticides in the 1st pre-blossom applications (about the mouse-ear stage). The result was surprising. The application of an insecticide (e. g. E 605, lindane or lindane-DDT product), subject to thorough and timely spraying, gave a better and more reliable effect against most pests than did winter sprays (tar oil, DNC and combined products). Therefore, we requested several reliable commercial orchardists to leave out the winter spray applications in 1951 by way of experiment, and to replace these by adding insecticide to the 1st pre-blossom spray. The success of this treatment was so convincing that none of these orchardists has reverted to the use of winter sprays for treating their pome fruit trees, especially as they realise that an unpleasant spray application is thus saved, and the spraying programme has become a more economical proposition.

On the grounds of these results and the experience accumulated, we have generally recommended winter spraying, from 1952 onwards, only for the treatment of stone fruit and berries, pome orchards on farms, and neglected plantations. The cultivated apple and pear plantations of our commercial orchardists, on the other hand, are now being treated on an increasing scale only with insecticides added to the 1st pre-blossom spray, instead of with winter sprays. It is merely in tree stands suspected of being infested by San

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José scale that the practice of winter spraying with mineral oil products has been kept up, and supplemented by carrying out summer spray applications of E-products to give effective control of the pest.

Several years ago, winter sprays for late applications were developed in Switzerland; these products are made up of mineral oil and a phosphoric ester. They do not have an unpleasant effect on the skin, do not stain, are odourless and moreover harmless to young leaves and interplanted crops. They are however, more or less toxic depending upon the active substance used, more closely bound up with the time factor in respect of application, and the costs are higher than for winter spraying. We were not in favour of these new products at the outset because by adding insecticide to the 1st pre-blossom spray, we had developed a simpler and less expensive method. The post-winter or early pre-blossom spray application would have meant that our commercial orchardists must split up the 1st pre-blossom spray, thus having to carry out an earlier spray application of insecticide and a later scab spray. To agree to such additional work and greater costs would have been expecting too much of our orchardists, and in fact we did not wish to nor could we demand this.

However, as we had to make allowance for the fact that the oleo-phosphoric esters would become known also in the Lake Constance region, we took the precaution of spraying one product in 1956 and several products with different active substances in 1957 and 1958, in order to gain our own experience on the advantages and disadvantages of these new preparations. The 1958 results are given in the table.

In 1958, we added FOLIDOL Oil as insecticide to the 1st pre-blossom spray (500 g wettable sulphur + 200 g green copper to 1000 litres of water), by way of experiment. The effect given was better than that produced by the corresponding summer sprays which were applied at the same time in parallel tests. We did not learn of any unfavourable influences being caused by the mineral oil components after leafing.

Many orchardists no longer like to carry out winter spraying because on the one hand the tar oils cause unpleasant irritation of the skin, and on the other hand DNC and DNBP leave an intensive yellow stain on the skin. The advertising campaign organised by the industry last spring for oleo-phosphoric esters met, therefore, with good results. More orchardists are less concerned about the toxicity of the new products than about the above-mentioned disadvantages of the winter sprays.

As a result, we were also able to observe the effect of oleo-phosphoric esters in plantations sprayed by the owners themselves. Usually the results obtained were the same as those recorded in our own tests. The best results were given when the treatment was carried out after bud-breaking. We therefore call the treatment bud-burst spraying and the oleo-phosphoric esters bud-burst sprays. It would be advisable to use these terms generally in the German language (Austriebsspritzung and Austriebsspritzmittel).

As mentioned above, we were not in favour of the bud-burst sprays at first, but we have now changed our opinion for the following reasons:

1. Good effect (see above).
2. Usually, dandelions have not started to flower when the 1st pre-blossom spray is carried out at mouse-ear, so that the addition of insecticide

Table 1: Trial spraying 1958, apple orchard at Messmer-Stockach

| Plot        | Treatment                                    | Date   | Evaluation on 30. 4.                                                                           | Evaluation on 21. 5. (per 50 bud resp. leaf clusters) |             |                                |                    |                    | Remarks                |
|-------------|----------------------------------------------|--------|------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------------|--------------------------------|--------------------|--------------------|------------------------|
|             |                                              |        |                                                                                                | Codling moth                                          | Winter-moth | Suckers                        | Aphids             | Spider mites       |                        |
| I top       | 0.5% FOLIDOL Oil                             | 2. 4.  | all dead                                                                                       | 1                                                     | 3           | —                              | —                  | slight infestation | 1 apple blossom weevil |
| V top       | 0.5% WS + 0.2% Cu + 0.5% FOLIDOL Oil         | 22. 4. | all dead                                                                                       | —                                                     | 6           | 4                              | —                  | slight infestation | 1 leaf scab            |
| VIII top    | untreated                                    | —      | same as plot VIII bottom                                                                       | 3                                                     | 32          | slight to moderate infestation | isolated           | moderate           | —                      |
| I bottom    | 0.5% WS + 0.2% Cu + 0.035% E605 conc. liquid | 22. 4. | suckers and aphids dead, isolated live caterpillars                                            | 1                                                     | 12          | —                              | —                  | isolated           | —                      |
| VIII bottom | untreated                                    | —      | few aphids, abundance of wintermoth, few codling moth, abundance of suckers (up to 10 per bud) | 11                                                    | 38          | slight infestation             | slight infestation | moderate           | —                      |

Each plot consisted of 22 apple bushes

Cu = green copper  
NS = wettable sulphur



does not constitute a hazard to bees. However, if the dandelions are already in bloom as in 1958, for example, then it may be desired to carry out the insecticidal spray earlier to protect the bees.

3. The first scab infections on apples and pears occurred very early in recent years in the Lake Constance region, often before the mouse-ear stage. In 1956 the first infections were observed about April 16, in 1957 on March 28, and in 1958 — less serious due to drop of temperature — on April 16 again. In order to ensure that scab will be effectively controlled, it may also be desired to carry out the 1st scab spray earlier (addition of 200—300 g of green copper to the bud-burst spray).

In tests carried out so far, the bud-burst sprays (e. g. FOLIDOL Oil) were more effective than the corresponding summer sprays. It still has to be established whether the increased effect is due to a higher content of active substance, to the content of mineral oil or to especially favourable physical properties. Further comparative trial sprayings with oleo-phosphoric esters and the corresponding summer sprays at bud-burst will have to be carried out in order to establish more clearly to what extent these applications are worthwhile.

## Report on the application of different insecticides for the first pre-blossom spraying and the use of oleo-phosphoric esters for the second pre-blossom spraying, 1958

by v. Rosenberg, Heilbronn/Neckar.

The selection of the right insecticide for the first pre-blossom spraying operation involves certain difficulties. In the author's district, the use of lindane + DDT products at concentrations of 0.3 % applied on a large-scale over a period of many years, chiefly against overwintering codling moth larvae, did not produce satisfactory results. It should, however, be taken into consideration that the spraying time had always been fixed according to the first possible outbreak of scab infection. No allowance was made for the development stage of the insects so that the time chosen for spraying was usually too late for an optimal insect control.

In order to clarify the question which group of products can be successfully applied in the first spraying operation, especially against overwintering codling moth larvae, spraying tests were carried out in the Heilbronn area, in a section of an eleven-year-old apple plantation on EM IX, which was very severely colonized by caterpillars of summer fruit tortricid; this infestation came about because a control of codling moth with phosphoric esters was not carried out in the autumn of 1957. More than 60 % of the fruit on the heavily laden trees were damaged.

Although the month of March was warm, cold weather with falls of snow prevailed in the first half of April, checking development completely. The "Goldparmäne" variety was in the initial mouse ear stage. The extremely abundant green apple aphid had already hatched out by the end of March. In mid-April the temperature started to rise; the first codling moth caterpillars migrated from their winter hiding-places. It was at this time, on April 15, 1958, that the test sprays were carried out. Six rows were sprayed with each of the following products:

- a) Lindane + DDT at 0.3 %
- b) E 605® forte 0.035 %
- c) FOLIDOL® Oil Spray at 0.5 %

The weather was dry, and the temperatures ranged from 12 to 15° C. The first scab spray application was carried out later. The other plantation was treated on April 17 and 18 with another phosphoric ester product applied at a concentration of 0.12 % (d).

The counts were made after seven and ten days, respectively, for a) to c) within the two middle rows, for d) immediately adjoining, also separated by four rows. In each case 100 caterpillars were counted twice at three-day intervals. The two results did not differ at all for d), and only insignificantly for a) to c). The following percentages were obtained from both counts:

| Total  |        |      | In buds and on<br>shoo's |        |      | In winter hiding-<br>places |        |      |
|--------|--------|------|--------------------------|--------|------|-----------------------------|--------|------|
| Total  | living | dead | Total                    | living | dead | Total                       | living | dead |
| a) 100 | 60     | 40   | 81                       | 47     | 34   | 19                          | 13     | 6    |
| b) 100 | 17     | 83   | 89                       | 17     | 72   | 11                          | 0      | 11   |
| c) 100 | 3      | 97   | 34                       | 1      | 33   | 66                          | 2      | 64   |
| d) 100 | 18     | 82   | 84                       | 16     | 68   | 16                          | 2      | 14   |

The green apple aphid which was weakened by the preceding unfavourable weather conditions, was in each case completely eradicated. With respect to the codling moth caterpillars, the pronounced differences in the "Total" column above all reflect the clear superiority of FOLIDOL Oil Spray, and also in this case the unsatisfactory effect of lindane + DDT. The effect given by the two phosphoric ester products (b and d) is almost the same for both, although it should have been better.

The rapidity of the toxic effect and the translaminar action of the poison can be concluded from the place where the caterpillars were found. The fastest initial effect was given by FOLIDOL Oil Spray. About two-thirds of the caterpillars were found still in their winter hiding-places; they were nearly all dead. Either they were killed due to the translaminar effect, or else, on leaving their winter hiding-places they came into contact with the spray deposit, immediately returned to these hiding-places and then died. For all the other products, 81 to 89 % of the caterpillars were already in the buds or on their way there. Therefore, the effect set in later. For the phosphoric ester products,

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it was found that 72 % of the caterpillars were killed outside the winter quarters by b), and 68 % by d); lindane + DDT gave a kill of only 33 %. As the second count carried out after an interval of three days produced almost the same results, it can hardly be assumed that there would be any change in these results at an even later date.

In order to become more closely familiar with the effect of oleo-phosphoric ester, and also to establish the possibility of leaf injuries when the product is applied alone and sprayed in combination with wettable sulphur, more spray applications were carried out on April 30, 1958, supplementary to the above test. The temperature was in the region of 20° C, and the weather conditions were sunny and dry. The plants were in the green cluster stage. A few pink buds were already present on the "Goldparmäne" variety (on EM IX). The rose twist moth was about to hatch out. For this spraying operation, the eggs of this moth as well as buds where the codling moth caterpillars had already made cocoons, were marked.

Two oleo-phosphoric ester products (including FOLIDOL Oil Spray) were applied at 0.5 % wettable sulphur.

The check was carried out on May 2. Whereas nearly all rose twist moth had hatched out in the plantation by this date, no caterpillars developed from the eggs sprayed in the test. Furthermore, all codling moth caterpillars in cocoons were killed. This observation indicates that oleo-phosphoric esters have a translaminar action. No leaf injuries whatsoever were observed, not even at a later date.

## Relations between time of controls and phenological data with respect to several pests occurring on peas and beans

by C. J. H. Franssen,

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Before chemical products were introduced for controlling insects, farmers and growers had to rely on cultural practices for preventing damage to crops. The accumulation of practical experience led to the adoption of certain crop rotations. It was known, for example, that a number of crops which were planted in the flax stubble, were likely to suffer serious disturbances of growth in early Spring, although the reasons for these disturbances had not been established. Today it is known that flax and also a number of other plants are capable of infesting the soil with *Thrips angusticeps* Uzel.

For this reason such fields colonized by *Thrips* were set only with late crops or with plants resistant to thrips. Another cultural practice which can check injuries to crops by insects or diseases is early or late sowing. Thus infestation by a certain parasite can be shifted to an earlier or a later stage in the growth of the plant whereby under certain conditions damage may be avoided.



Furthermore certain plants are sown as far away as possible from plots where these plants were grown in the previous year. This practice is followed especially in the cultivation of flax. Besides *Thrips angusticeps*, another species, *Thrips linarius* Uzel, also overwinters in flax stubble. Therefore when flax is sown in plots adjoining flax stubble there is the danger not only of the crop being damaged by peripheral infections — known as “trident symptoms” — and caused by *Thrips angusticeps*, but also of large-scale infestation by *Thrips linarius* Uzel. As already stated, the cultivation of certain plants has for some considerable time past been governed by the adoption of such protective cultural practices, and in our opinion the employment of these practices is fully justified even today. However, cultural practices can, as far as necessary, be supplemented and given added effect by using the chemical products that are now available for controlling pests.

### I. The influence of the date of spraying on the success of controls

If a control operation using chemical products is to be fully effective, it is primarily essential that this control is properly timed. A major condition for ensuring correct timing of controls is that one is sufficiently familiar with the phenology of the insect involved.

The gall midge, *Contarinia nasturtii* Kieffer (*C. torquens* de Meij.) causes, for example, cabbage top. In 1935, this insect inflicted such considerable damage to crops in North Holland that it was doubtful whether the cultivation of cabbage could be continued. Chemicals were sprayed but the results were extremely varied and uncertain because it was not known when the best time was for controlling the insect. After making a careful study of the phenology of this midge, Leefmans (1937, 1938, 1939 and 1940) was able to specify the times for spraying, and the problem was thus solved for farmers.

Leefmans also revealed that the timing of chemical spray applications may be of decisive importance in the control of insects and that, at least in the case of *Contarinia nasturtii*, the most favourable time for carrying out a control is largely determined by the phenology of the midges.

In Holland, Leefmans paved the way for the recognition of phenology in applied entomology or in other words for the introduction of applied phenology. The aim of this scientific trend is to facilitate the implementation of a control, which is based on the phenology of the insect that has to be eradicated. Applied phenology, therefore, mainly fulfils the task of bringing to light phenological facts which may be of importance for fixing the time of controls.

It is confirmed, for example, that the short-winged *Thrips angusticeps* starts to leave the ground when the temperature has risen above a certain limit. It is also confirmed that the hatching out of thrips extends over a lengthy period, and that a large part of the thrips population present in the soil is swarmed out and starved before the summer plants germinate. It is not, however, the task of applied phenology to establish the real underlying reasons for these phenomena; questions connected hereto must be clarified by basic research.

## II. Phenology of a parasite and development of its plant host in relation to damage

The phenology of certain pests and the stage of growth in which the plant host may be attacked, are usually closely linked. Slight natural displacements in this relationship may have great influence on the damage caused, as shown by the following examples.

In Holland it is generally the larval stages only of *Kakothrips robustus* Uzel which cause severe damage to flower buds and young pods. The thrips usually appears in Holland in the second half of May, and the first larvae are observed in the latter half of June. By this time the pods of very early pea varieties are already fully developed everywhere so that they avoid damage by *Kakothrips robustus*. On later varieties the upper pods may be attacked and deformed, and on very late varieties or earlies that are sown late, the top buds may be attacked causing them to shed. This latter injury which has the most serious consequences, was observed in 1957 on field peas which in Holland very seldom suffer such damage to the blooms. In this particular year, 1957, the thrips occurred about two weeks earlier than usual, and furthermore larvae were found on much younger stages of pea growth than is generally the case.

Another example is *Thrips angusticeps* which has already been referred to several times. The larvae of the long-winged generation (direct progeny of the short-winged thrips) occur at a most early stage of flax growth and, like the adult flax thrips, are capable of causing abnormal growth in the terminal bud, known in Holland as "kwade koppen". The adult, long-winged *Thrips angusticeps*, on the other hand, which migrate to flax, usually do not appear on this crop until the flax is more or less fully developed. This explains why this thrips species which colonizes the top parts of the plants, does not usually cause such abnormal growth of the kind known as being characteristic of the injury inflicted by larvae. But owing to the prevailing weather conditions, the long-winged *Thrips angusticeps* occurred much earlier in 1957 with the result that in this particular year it caused the kind of damage otherwise observed only when the larvae occur.

## III. Phenology of the pest and the growth stage of the plant host in relation to time of spraying

The relationship existing between the phenology of the pest and the growth stage of the host does not only have bearing upon the damage to the crops but is also of considerable importance for fixing the time of the treatment. In deciding when to carry out spray applications, it is in most cases merely necessary to make allowance for the phenology of the insect. This applies, for example, to the aforementioned midge species *Contarinia nasturtii*. The chemical control of this insect, therefore, is based on observing when the first eggs are laid on cabbage plants. It is recommended to spray once weekly during the midge flight, and to start spraying as soon as the first eggs are laid.

Similar cases are also to be found among other noxious insects attacking legumes, which are mentioned later.

In this paper, the author wishes to point out that in fixing the most favourable time for carrying out controls it is not always sufficient to make allowance only for the phenology of the insect concerned but that rathermore the growth stage of the plant host may also be of importance.

Several examples of this are taken from a number of investigations carried out by the author, which deal exclusively with the control of harmful insects on legumes.

#### IV. Timing the control

In Holland, there are several possibilities for fixing the time for carrying out sprays against a number of major pests that attack legumes. Besides those cases where the development of the plant host and the insect must be given consideration, there are other cases where the phenology of the insect can be left completely unconsidered for fixing the time of controls, which here can be based solely on the growth stage of the plants.

##### 1. Treatment based on phenology of insect

In this case it is not difficult to choose a favourable time for carrying out controls, it being sufficient here to take the occurrence of the pest or the disease symptom as the guiding factor.

This applies for example, to the pea leaf weevil (*Sitona lineatus* L.), to *Thrips angusticeps* and to pea moth (*Enarmonia nigricana* F.).

The last-mentioned of these pests can, however, be successfully controlled when allowance is made in timing the applications solely for the growth stage of the plant host (cf. 2b).

The pea leaf weevil overwinters in Holland primarily in alfalfa and clover fields; then it migrates in more or less abundant numbers to peas where it causes damage to the young plants, and lays its eggs.

The serious damage is caused by the larvae and not by the adult weevils; the larvae first feed on the root tubercles and later attack the roots of young pea plants. The control must, therefore, be timed so as to prevent the weevil laying eggs, which means that sprays must be applied as soon as the first injuries caused by feeding are observed on the leaves or when the first weevils are seen in the crop.

Spray applications aimed at controlling *Thrips angusticeps* which attacks other crops in addition to peas in early Spring, must also be started when the first thrips or the first symptoms of attack are observed. Controls of *Kakothrips robustus* should commence as soon as the first larvae occur because it is the larval stages which are mainly responsible for the damage caused by this pest. Furthermore, treatments against *Enarmonia nigricana* should commence when the first juvenile caterpillars are observed on the pods.

##### 2. Time of spraying in relation to the growth stage of the plant

a) Those pests which attack and harm their plant host only at a certain stage in the growth of the plant always colonize the plants before the latter reach this stage of development.



Examples of such pests are the broadbean weevil (*Bruchus rufimanus* Boh.), the bean weevil (*Acanthoscelides obtectus* Say) and the pea midge (*Contarinia pisi* Winn.) on field peas. Therefore, in fixing the time of spraying it is not possible to allow for the phenology of these parasites. In the case of *Bruchus rufimanus*, the controls are directed against the adult weevils which are already feeding on the young plants. The weevils are found on extrafloral nectaries and in the blossoms. Sprays against this pest must be applied as soon as the floral leaves of the oldest blossoms begin to wilt. Although the weevils are then on the plants, they have not yet had an opportunity to lay eggs because no pods have been formed.

The occurrences of the bean weevil in Holland are so sporadic that usually controls are not carried out against this pest. Neither the green nor the yellow pods are attacked by the weevils but as soon as the pods begin to dry they are infested and it is in these pods only that the eggs are laid. Here, too, one again finds a relationship between the stage of plant growth and the start of the infestation period.

Assuming that the weevils behave in other countries just as they do in Holland, then spraying must be started at this particular time in regions where there is likelihood of the weevils causing severe damage.

The pea midge, too, can be controlled — at least on field peas but not on early garden varieties — at a time which depends only upon the development of the plant. The treatment should be carried out when the young flower buds are accessible to the midges (cf 3).

b) The phenology of the pest is so closely linked with the development of the plant host that the time for spraying can be also fixed according to the stage of plant growth.

An example of this is provided by the aforementioned pea moth. The moths are attracted by the blossoms and lay their eggs almost exclusively on flowering pea plants. The preovipositional stage and the egg stage together last so long that the first caterpillars against which the control is directed, are not observed until some time after the first flowers have formed and after the appearance of the first moths on the plants. On peas that are sown at the usual time (late February to early April), the first caterpillars can generally be expected when the peas of the bottom pods on peripheral plants have grown to about three-quarters their full size. It is understandable that the first attack by caterpillars does not take place at an exactly fixed time but that it can occur sometimes earlier and sometimes later. A large number of various factors have bearing upon this, the most important being the start of the blossom period, the rate of plant growth, the start of the moth flight, the duration of the preovipositional stage and the duration of the egg stage.

The first two factors are governed by the variety, the time of sowing and the climatic conditions.

The start of the moth flight is influenced, inter alia, by the climate and by the kind of soil. The temperature has really great bearing upon the duration of the preovipositional stage and the egg stage. Another factor that may have influence on the time of the first attack is the distance between the pea field and the nearest source of infestation.

In Holland, all the above-mentioned factors form at least a more or less stable balance with the result that when plants are sown at the usual time,

infestation takes place under practical conditions at the time given above. However, as the plants at the edge of the field usually start flowering before the others, eggs are laid on these plants first, and it is also here that caterpillars are found as a rule earlier than in other parts of the field.

Peas that are sown very late may also be attacked at an earlier time. Later in the season, the mean daily temperature is usually higher so that the sum of the above factors is then different. The same effect is also recorded in unusually warm years.

Therefore, the time for controlling the pea moth can be fixed according to both the stage of plant growth and the appearance of the young caterpillars (cf 1).

### 3. Time of spraying in relation to the development stage of the plant and the noxious insect

In this case, growers and farmers must consider two factors. An example is provided here by the pea midge. This pest can only attack its plant host from a certain growth stage onwards. The midge may, however, occur before this stage is reached, as soon as it is reached or later.

The midge lays its eggs in the young flower buds of the pea plants. In Holland, the pea midge usually occurs in the latter half of May. It cannot attack the plants, however, until the first flower buds are accessible, in other words when the leaflets between which the flower buds are embedded, have unfolded. It is often observed that midges have not yet appeared on early garden varieties when the plants reach this critical stage of growth.

In order to fix the time for spraying, it is, therefore, necessary to follow at first the development of the plants, and from the moment when the young flower buds form a watch must be kept for the occurrence of the first midges. The control should be started as soon as the first midges are detected. In the case of field pea varieties that flower later, midges are usually present in large numbers in Holland by the time these plants have grown to the stage when it is necessary to spray. This means, that here the time of the treatment can be fixed solely according to the development stage of the peas (cf 2a).

### 4. Preventing or minimizing damage by breaking the relationship between the phenology of the host and the parasite

It is evident from what has already been said that in many cases there is a very definite relationship between the occurrence of a parasite and the endangered stage in the growth of the host. Therefore, if this relationship can be successfully broken there is every prospect of minimizing damage to the crop. This possibility actually exists for several pests that attack our legumes. As the phenology of the parasite practically depends solely upon the weather conditions, the relationship can only be broken through the plant host. The best known examples for effecting this include, as already mentioned above, early sowing and shortening the stage in which there is danger of infestation. A few other examples will be given to explain these possibilities. If the development of the peas is retarded due to late sowing or poor weather conditions, these plants will be very severely attacked by pea thrips. The reason for this is that the thrips larvae which are mainly responsible for the damage caused,

do not occur until relatively late in the season. Therefore, there is less danger of early sown peas or early varieties being harmed. Even in areas where the pea thrips usually causes severe damage, for example in West-Nieuwland polder near Ouddorp, early varieties generally may not be harmed at all.

In some growing districts, peas are sown under glass, and later transplanted in the field. Here, the peas begin to flower already in April, and the blossom period is over when the first pea midges appear. Therefore, the midges cannot cause any damage at all due to the absence of flower buds when they occur. The very early blossom in conjunction with the phenology of the midges therefore offers here special advantages. Early garden varieties, too, usually flower at such an early time in the season that there is no danger of the crops being severely harmed by the pea midge. It has, however, been shown that infestation of our field peas is all the more severe the later the peas flower.

Furthermore, long-flowering varieties suffer greater harm from midge attacks than varieties with a short blossom because they are exposed to attack over a longer period.

The facts that have been outlined in this respect for the pea midge also apply to the pea moth. Very early peas that are germinated under glass before being transplanted in the field are not harmed at all by the moth, and also other varieties that flower very early and which blossom before the moth flight begins, more or less avoid infestation. Varieties with a short blossom are also colonized by the moth for a shorter period because, as already pointed out, the moth is attracted by the flowers. Consequently, these varieties are usually less severely attacked.

The bean weevil requires a minimum outdoor temperature of  $19^{\circ}\text{C}$  and fully grown plants in order to lay its eggs.

The later the plants reach this stage of completed growth (or stage of infestation hazard), the less danger there will be of them being attacked in view of the other factor, namely the minimum temperature.

In France where, in contrast to Holland, the weevil may occur in large numbers, it is recommended to plant very late varieties which do not reach the endangered stage of growth until mid-September, or else to sow the plants so late that they will be ready for harvesting at the end of October or in November (Labeyrie, 1957). It appears that cultivation in France is so well organized that healthy beans are harvested even in areas of severe weevil occurrence.

The examples given here show how many alternative ways there are for preventing or minimizing damage by breaking the temporal relationships that exist between plant host and parasite.

Even though this paper has been essentially confined to a few examples of pests that occur on legumes, it should again be emphasized that such possibilities as outlined here naturally apply to a large number of other pests and crops.



# Studies on the Germination Biology of Conidia of *Uncinula necator* (Schwein.) Burr.

by M. Weltzien-Stenzel

## I. Introduction

Despite numerous studies and observations, relatively little is still known of the causes which lead to mass incidence in the field of *Uncinula necator* (Schwein.) Burr., powdery mildew on grape vines. According to Yossifovitch (1923), conidia can germinate over a wide range of temperature and relative humidity. The varying severity of infection which has been observed both in the field and in greenhouses, must therefore be attributed also to other factors. Furthermore, few reports have so far been published on changes in the diathesis of grape vines to mildew infection. The illustrations of differently nourished potted grape vines, published by Schaffnit and Volk (1930), demonstrate the strong reaction of the plants to feeding conditions. These differences in growth also corresponded to the varying degree of mildew infection. Husfeld (1934) expressed similar views.

The question arose, therefore, whether the exploratory studies of Yossifovitch on the germination of conidia at different temperatures and relative humidity, had made no allowance for essential climatic factors or whether the intimated contradiction may be explained by the existence of a relationship between the development of the parasite and the diathesis of the host, which has so far not been clearly recognised. Therefore, the dependence of the germination of conidia on the effect of various ambient conditions was investigated in this study. In addition, the incidence of the fungus in greenhouses was observed, and compared with the results of the germination tests.

## II. Test material and general method

One- to two-year-old single bud cuttings of the Silvaner and Elbling varieties were potted in garden soil, and placed in several cabins of the Institute greenhouse. The plants were exposed to spontaneous infection of *Uncinula necator*. The severity of infection was the same on both varieties, and apart from slight differences the symptoms were also the same. The conidia were always directly transferred from the leaf to the germinating substrate; use was made only of turgescient material from fresh sites of infection. The conidia were removed from the leaf with a camel's-hair brush, and distributed on the substrate by means of a needle. The density of conidia fluctuated between 50 and 100 conidia per square centimetre, but had no bearing on germination. The germinated and non-germinated conidia (magnification  $\times 35$ ) were counted, and the germination was expressed as a percentage of the total germination number. For 6 to 8 replications, the different means are based on numbers of conidia of between 2000 and 3000. Statistically, the means were worked out with the aid of the t-test (Linder, 1951) or according to the analysis of variation method (Linder l. c.; Snedecor, 1946); in each case the method was first checked for admissibility. As far as necessary, the standard deviation

$\sqrt{\frac{\sum (x - \bar{x})^2}{n \cdot (n - 1)}}$  is allowed for in the tables.

### III. Conditions for the germination of conidia in the laboratory test

Yossifovitch carried out germination tests with *U. necator* both on glass as well as in hanging drops. He obtained slightly and greatly deviating germination numbers like many other authors who conducted studies on Erysiphaceae (Woodward, 1927; Clayton, 1942; Metzger, 1942; Cherevick, 1944; Meyer, 1951). The causes of these variations were attributed on the one hand to substrate properties of hitherto unknown effect (Woodward, 1927; Stoll, 1941; Metzger, 1942), and on the other hand to a change in the germinating capacity of the conidia prior to the actual process of germination (Neger, 1902; Longrée, 1939; Clayton, 1942; Cherevick, 1944; Meyer, 1951). I, therefore, first of all tested different substrates in the germination test.

#### 1. The effect of different substrates on germination

##### a) Water as germinating substrate

Conidia of *Erysiphe graminis*, *E. polygoni*, *Sphaerotheca pannosa* and *Podosphaera leucotricha* completely or partially lose their germinating power when suspended in water (Rauch, 1895; Neger l. c.; Maurizio, 1927; Graf-Marín, 1934; Longrée l. c.; Clayton l. c.; Grainger, 1947; Domsch, 1954). As Yossifovitch reports that conidia of *U. necator* germinated in hanging drops, and moreover as their susceptibility to water is of interest from the biological and epidemiological aspect, the germination of conidia suspended in water drops and floating on water drops was compared with their reaction on a collodion membrane mounted over a water drop. Table 1 gives the values thus obtained.

Table 1: Average germination of conidia expressed in % in and on a water drop, and on collodion membranes

| Check:<br>Membrane over water |               | in water<br>drop |               | on water<br>drop |               |
|-------------------------------|---------------|------------------|---------------|------------------|---------------|
| $\bar{x}$                     | $s_{\bar{x}}$ | $\bar{x}$        | $s_{\bar{x}}$ | $\bar{x}$        | $s_{\bar{x}}$ |
| 84.6                          | 1.1           | 52.9             | 4.3           | —                | —             |
| 74.7                          | 2.0           | —                | —             | 54.5             | 3.9           |
| 86.8                          | 1.8           | —                | —             | 76.2             | 2.3           |

They show that conidia of *U. necator* are susceptible to coverage with water. Most of the suspended conidia had deflated and perished after 48 hours, whereas the conidia floating on the water surface maintained their normal turgescence for a period of one week.

##### b) Water-discharging germinating substrates

Woodward (1927) and Longrée (1939) obtained in tests with conidia of *P. leucotricha* and *S. pannosa*, an appreciably higher germination number on leaves of the respective host plants than in hanging drops or on glass. Whereas Woodward was of the opinion that the better germination was due to a

stimulation emanating from the host, Longrée who had recorded a higher germination number also on substrates other than host leaves, attributed this to the high and constant relative humidity on the leaf surface. Stoll (1941) prepared collodion membranes on which he obtained an increased germination number for *P. leucotricha*. He concluded that the membrane exerted a contact stimulation on the conidia; Johnson (1934) and Dickinson (1949) also considered this to be necessary for the growth of certain obligate parasites. The effect of such substrates on the germination of *U. necator* was, therefore, tested and collodion membranes, agar, gelatin and leaves were examined for their suitability.

To prepare the collodion membranes, use was made of collodion cotton (supplied by Messrs. Wolff u. Co., Walsrode) dissolved in alcohol 96 % and sulphuric ether (ratio of 15:79). By applying this solution onto a dry slide free of fat, a fine membrane is formed which can be washed away in water. The membrane was used in three different ways for the germination tests: 1) by mounting it over a glass ring filled with water and firmly cemented to a slide; 2) by mounting it over glass rings not filled with water; 3) by leaving it on the slide. For the preparation of the agar or gelatin plates which were occasionally used, 2 % water agar or 15 % water gelatin was taken. To count the conidia that had germinated on the leaves, drops of collodion were applied to the respective parts of the leaves and the membrane was then removed. The conidia then adhered to the membrane and as a result could be counted. In moist chambers, germination took place at room temperature and was established after 48 hours. The results are given in Table 2.

Table 2: Average germination number expressed in %, on different substrates

| Substrate                      | $\bar{x}$ | $s_{\bar{x}}$ |
|--------------------------------|-----------|---------------|
| Living grape vine leaf         | 67.3      | 1.8           |
| Collodion membrane on water    | 81.4      | 1.3           |
| Collodion membrane mounted dry | 53.7      | 3.0           |
| Collodion membrane on glass    | 60.6      | 1.9           |
| Agar plates                    | 53.6      | 2.4           |
| Gelatin plates                 | 41.6      | 1.6           |
| Glass                          | 37.8      | 8.6           |

It is seen that germination of conidia was by far the best on membranes mounted over water. On grape vine leaves and dry membranes, the rate of germination was significantly higher than on glass; germination on glass corresponded to that on gelatin. Germ tubes that formed on leaves differed from those formed on other substrates. Usually a short germ tube with an appressorium (Fig. 1) developed on the membranes; two germ tubes, a short one with appressorium and a long, non-ramified one, frequently formed on the leaves (Fig. 1).



Although it was to be assumed that the high germination percentages produced on membranes mounted over water were the result of favourable moisture conditions, it was nevertheless investigated whether germination is also influenced by a change in the structure of the membrane. Comparative tests on membranes removed from leaves and slides did not, however, show any differences in the germination percentages. Furthermore, differences in the concentration of the collodion solution ranging from 1 to 3% had no influence on germination. The use of leaf extracts, press juice from leaves and glucose solution, poured into the glass rings instead of water, did not increase germination, either. I therefore tested the membranes for their permeability by

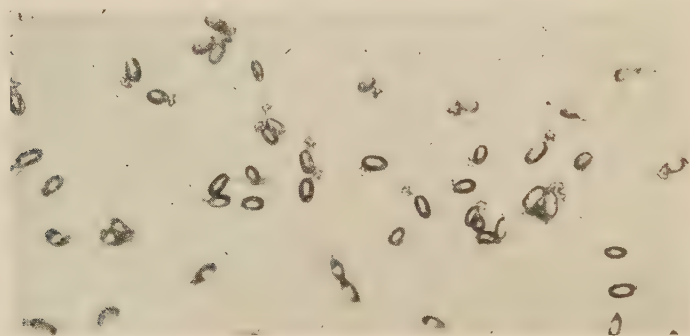


Fig. 1: Germinating conidia on the collodion membrane

locating them over a 0.1% sublimate solution; for the purpose of comparison, germination was effected on sublimate without using a membrane, and on a membrane located over water. The results are given in Table 3.

Table 3: Average germination expressed in % on 0.1 % sublimate solution and on membranes located over same solution

| Substrate                         | $\bar{x}$ | $s_x$ |
|-----------------------------------|-----------|-------|
| Membranes on water                | 84.5      | 0.9   |
| Membranes on 0.1% sublimate       | 40.1      | 3.3   |
| 0.1% sublimate (without membrane) | 35.6      | 1.7   |

The membrane is thus permeable to the sublimate solution. The only explanation for the fact that conidia were at all able to germinate on this solution, is that a high percentage of them were not wetted.

The tests outlined so far have shown that collodion membranes mounted on water bring about high and relatively constant germination percentages, such as

have not been attained with the methods hitherto described for *U. necator*. Other advantages of this method are that the substrate has no unwanted secondary effects, furthermore differences in the preparation and mounting of the membrane have no influence on the result, and membranes can be prepared quickly and easily. When mounted over water, they were used for this reason as the standard substrate for further studies.

## 2. Influence of light

As it has been proved that light stimulates germination of other species of Erysiphaceae (Neger, 1902 for *Erysiphe* spec. on *Ranunculus*, Yarwood, 1936 for *Erysiphe polygoni*, Cherewick, 1944 and Pratt, 1944 for *E. graminis*), it was first established whether such an influence is also exerted on *U. necator*. 40, 60, 100 and 200 watt Osram bulbs, placed 35 cm above the conidia, were used for lighting. The results are given in Table 4.

Table 4: Average germination expressed in % for varying periods of lighting

|               | Daylight | Period of artificial lighting in hours |      |      |      |      |      |      |      |
|---------------|----------|----------------------------------------|------|------|------|------|------|------|------|
|               |          | 24                                     | 12   | 8    | 4    | 3    | 2    | 1    | 0    |
| $\bar{x}$     | 76.9     | 75.1                                   | 67.7 | 70.4 | 66.4 | 60.2 | 63.7 | 61.7 | 42.0 |
| $s^2 \bar{x}$ | 1.4      | 1.4                                    | 3.7  | 1.0  | 1.6  | 1.2  | 2.3  | 2.4  | 2.0  |

It was at first revealed that gemination is definitely stimulated by light, so that it is thus necessary to carry out germination tests in light. There is no difference between the germination numbers obtained for daylight and for 24 hour artificial lighting. The germination numbers decreased as the period of lighting lessened. The values from 66.4 downwards are statistically significant as compared with 75.1. On the other hand, one hour lighting also produced significant, increased germination numbers as compared with germination in darkness. The varying degree of light intensity had no influence on germination.

## 3. Influence of other factors on germination of conidia

Appreciable variations have always been observed with respect to the germinating power of *U. necator* and also for all other Erysiphaceae which have been carefully studied. Although it was possible to eliminate methodical errors by using collodion membranes, considerable deviations nevertheless remained under otherwise similar conditions. It was assumed that these deviations resulted from factors which act on the conidia during their formation on the host. As this apparently is a very important question from the epidemiological aspect with respect to the possibility of constituting a characteristic of Erysiphaceae, attention was given to it.

### a) Germinating power in relation to age of conidia

Several authors report that old, fallen conidia of Erysiphaceae do not germinate so well as young conidia seated on conidiophores (Neger, 1901; Graf-Marin, 1934). Longrée (l.c.) gives 24 hours as the maximum age for *S. pannosa*; the maximum age for *E. graminis* is put down at 2 days by Metzger (1942), whereas Clayton (1942) and Meyer (1942) only obtained varying germination numbers with young conidia of the same species. According to Yarwood (1936), 1 to 4 day old conidia of *E. polygoni* germinated equally well. A certain maturity condition is assumed by Foreman (1910) and Domsch (1953) as being responsible for the high germinating power of conidia and the fructiferous mycelium of *Sphaerotheca mors-uvae* and *E. graminis*, respectively.

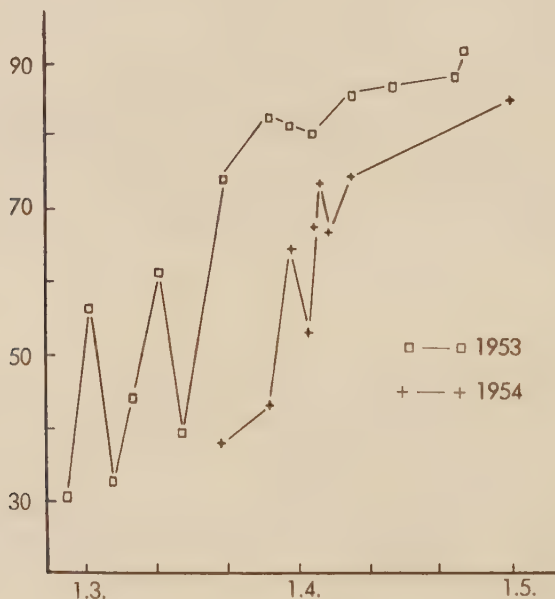


Fig. 2: Increase of germination in spring 1953 and 1954

Abscissa: Dates of test

Ordinate: Germination expressed in %

In the case of *U. necator*, it proved to be impossible, due to the long conidial chain (6 to 8 conidia), to cause conidia of equal age to germinate. Therefore, conidia from young, growing infection sites on terminal leaves and from old, defined infection sites on the oldest leaves were compared with each other. Table 5 gives the germination figures obtained on different dates. Except for the values obtained on June 9, the differences between the simultaneously

recorded germination numbers are statistically significant ( $p < 1\%$ ). This shows that maximum germination numbers can only be expected with conidia taken from young infection sites.

Table 5: Average germination expressed in % for conidia taken from young and old leaves

| Date of test  | Conidia from |                |            |                |
|---------------|--------------|----------------|------------|----------------|
|               | young leaves |                | old leaves |                |
|               | x            | s <sub>x</sub> | x          | s <sub>x</sub> |
| 9. 6.         | 79.5         | 2.6            | 70.7       | 3.0            |
| 13. 6.        | 90.5         | 0.6            | 74.1       | 2.6            |
| 17. 6.        | 86.9         | 1.7            | 72.3       | 2.1            |
| 25. 7.        | 91.0         | 1.2            | 83.2       | 1.2            |
| total average | 87.0         |                | 75.1       |                |

#### b) Germinating power in relation to the time of day of conidia sampling

Yarwood (1936) established a diurnal cycle for the germination of *E. polygoni*, but not for *E. graminis*. He stated that the long conidial chain is responsible for the lack of diurnal cycle in the case of the latter species. *U. necator* also has a long conidial chain, so that a similar result was anticipated. Sampling of conidia at 12 a.m., 4 p.m. and 6 p.m. resulted in a germination of 86.1, 87.6 and 80.4 %, respectively, so that apparently a diurnal cycle of germination is not to be expected.

#### c) Germinating power in relation to weather and season

Clayton (1942), Cherewick (1944), Yarwood (1936) and Meyer (1951) reported that the weather has an influence on the recorded germination numbers during the formation and germination of conidia; dull weather usually led to poor germination. Woodward (1927) obtained no germination with winter conidia of *P. leucotricha*.

I have never at any time observed that the germination of *U. necator* is dependent upon weather conditions, although seasonal influences were evident. Fig. 3 shows that the germination figures increased from 30–40 % to 80–90 % between March and May in 1953 and 1954; the variations were most marked. Other tests revealed that the low winter germination figures were the result of inadequate light. By exposing winter plants to additional lighting produced by means of an Osram tubular lamp installation, the germination number for the conidia that had formed on these plants increased within 2 weeks to an average of 81 %, thus corresponding to summer germination. But even then



the winter conidia germinated at a slower rate. The germination figures for the summer conidia reached a maximum after only 12 to 24 hours at the end of May, whereas the peak figures for germination of winter conidia in early January were not attained until after 48 hours had elapsed following exposure to additional lighting. In high summer, the germination numbers started to drop again in early August to a value of about 60 %. This decrease was associated with the stunted growth of the host plants that set in about the same time, and which was always accompanied by mass incidence of old, non-turgescant conidia.

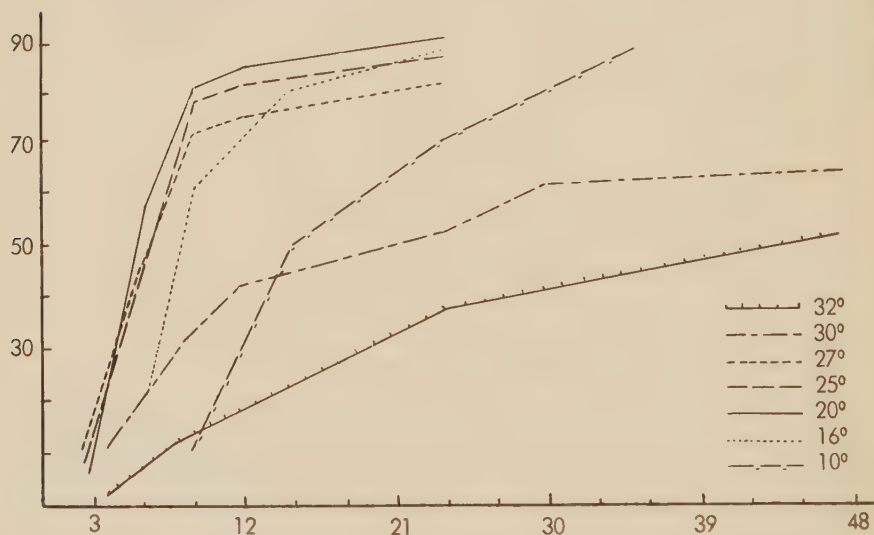


Fig. 3: Increase in germination at seven different temperatures  
 Abscissa: Times in hours  
 Ordinate: Germination in %

#### IV. Germination of conidia in various climatic conditions

Once the methods had been evolved for carrying out reproducible germination tests with conidia of *U. necator*, the influence of temperature and relative humidity — the climatic factors of greatest importance with respect to the epidemiology of the fungus — on germination was closely studied under controlled conditions.

##### 1. Effect of temperature on germination and germinating power

The only data available on temperature conditions required for the germination of *U. necator* conidia, are those published by Marès (1856), Viala (1893) and Yossifovitch (1923). They all give 25—27° C as being the most

favourable temperature for germination. Yossifovitch quotes 4.5 and 35 °C as the respective limits for conidial germination. His germination numbers vary so greatly, however — no doubt due to lack of method; e.g. between 4 and 40 % at 22 to 23 % — that it appeared advisable to carry out a renewed and extended study.

#### a) Germination of conidia at constant temperatures

All germination tests carried out at temperatures below 10 °C were run in cooling chambers with continuous lighting; all other tests were conducted in thermostats with glass walls, in daylight. The temperatures varied by  $\pm 0.5$  to  $\pm 1.0$  °C. Collodion membranes on water were used throughout as germinating substrates. Each test group included a comparison test run at 18 °C. The number of slides (n) examined in each case — each with approximately 450 counted conidia — is given below together with the results in Table 6. The test lasted 24 hours.

Table 6: Average germination numbers expressed in % at different temperatures and optimum relative humidity after 24 hours

| Temp. in °C | $\bar{x}$ | $s\bar{x}$ | n   |
|-------------|-----------|------------|-----|
| 3           | 0         | —          | 14  |
| 4.5         | 9.4       | 1.7        | 8   |
| 8           | 54.8      | 2.8        | 10  |
| 10          | 58.7      | 2.9        | 13  |
| 13          | 74.3      | 0.9        | 7   |
| 15          | 83.6      | 2.5        | 16  |
| 17          | 80.8      | 2.8        | 15  |
| 18          | 78.5      | 0.9        | 113 |
| 20          | 89.9      | 1.3        | 6   |
| 21          | 86.9      | 1.3        | 10  |
| 25          | 85.3      | 0.8        | 16  |
| 27          | 86.2      | 2.2        | 14  |
| 29          | 57.3      | 2.5        | 6   |
| 30          | 53.7      | 3.6        | 6   |
| 32          | 38.3      | 4.4        | 6   |
| 34          | 0         | —          | 6   |

The values obtained at temperatures ranging from 15 to 27 °C cannot be separated statistically, and thus constitute an extended optimum range for the germination of conidia. Lower and higher temperatures definitely lead to a decrease in the germination figures; the minimum and maximum temperatures are attained at 3 ° and 34 °C, respectively. The germination numbers decrease more rapidly at rising temperatures than at sinking temperatures.

b) Maintenance of germinating power at extreme temperatures

In summer, temperatures frequently prevail in the field and in greenhouses, which are above the optimum range for germination, but these persist for short periods only. Therefore, the maintenance of germinating power was tested at 29, 30, 32, 34, 36 and 38 °C, exposure periods of 2, 4, 8, 16, 24 and 48 h. At the end of the period of exposure to high temperature, the slides were then placed in chambers at a temperature of 22 °C, and the germination numbers were determined after a further 24 hours. The values for 48 hour period of temperature influence were the only ones to be recorded immediately after termination of exposure. A test series was run at 22 °C as a check. The results are given in Table 7.

Table 7: Average number of conidia expressed in % that germinated in optimum conditions following various periods of exposure to high temperatures.

| Test temperature<br>+ °C | Period of exposure expressed in hours |      |      |      |      |      | Check<br>22 °C |           |
|--------------------------|---------------------------------------|------|------|------|------|------|----------------|-----------|
|                          | 2                                     | 4    | 8    | 16   | 24   | 48   |                |           |
| 29                       | —                                     | 92.0 | 92.3 | 89.2 | 92.6 | 85.4 | 90.6           | $\bar{x}$ |
|                          |                                       | 0.4  | 1.1  | 1.4  | 2.0  | 1.7  | 0.9            | $s_x$     |
| 30                       | —                                     | 92.1 | 93.0 | 86.5 | 70.3 | 64.2 | 89.4           | $\bar{x}$ |
|                          |                                       | 1.5  | 0.6  | 1.7  | 2.9  | 2.6  | 1.8            | $s_x$     |
| 32                       | —                                     | 88.1 | 87.1 | 81.9 | 77.9 | 52.1 | 89.2           | $\bar{x}$ |
|                          |                                       | 1.9  | 1.0  | 3.7  | 5.0  | 3.9  | 1.4            | $s_x$     |
| 34                       | —                                     | 82.9 | 83.7 | 59.0 | 29.4 | 0    | 79.2           | $\bar{x}$ |
|                          |                                       | 3.2  | 1.7  | 4.4  | 3.2  | 0    | 1.8            | $s_x$     |
| 36                       | 84.2                                  | 68.3 | 10.1 | 0    | —    | —    | 86.1           | $\bar{x}$ |
|                          | 2.8                                   | 8.0  | 4.0  |      |      |      | 1.1            | $s_x$     |
| 38                       | 67.6                                  | 6.8  | 0    | —    | —    | —    | —              | $\bar{x}$ |
|                          | 2.3                                   | 2.5  |      |      |      |      |                | $s_x$     |

The test procedure enabled the limit to be established between inhibition of germination and initial mortality of spores. Whereas mortality does not begin until after 24 hours at 30 °C, it is most marked after only 2 hours at 38 °C. On the other hand, temperatures of up to 36 °C are tolerated without harm for at least 2 hours. This means that the conidia are well adapted to the summer temperatures prevailing in our climatic zone.

In a further series of tests, the reaction of the conidia to low temperatures was examined. The slides were placed in a dark cooling chamber for 14, 31 and 64 days at  $+4^{\circ}\text{C}$ , and for 14 days at  $-3^{\circ}\text{C}$ , followed by exposure to  $22^{\circ}\text{C}$  for germination. Table 8 gives the germination numbers obtained.

Table 8: Average number of conidia expressed in % that germinated in optimum conditions following various periods of exposure to temperatures of  $-3^{\circ}\text{C}$  and  $+4^{\circ}\text{C}$ .

| Period of exposure in days     | 14   |      | 31   | 64     | Check                 |
|--------------------------------|------|------|------|--------|-----------------------|
| Temperature $^{\circ}\text{C}$ | $-3$ | $+4$ | $+4$ | $+4$   | $+22^{\circ}\text{C}$ |
| Germination numbers $\bar{x}$  | 40.9 | 67.9 | 20.2 | traces | 81.1                  |
| $s_x$                          | 5.7  | 2.3  | 3.0  |        | 1.8                   |

The thin-walled, weak conidia tolerate temperatures in the region of  $+4^{\circ}\text{C}$  for surprisingly long periods without suffering serious harm, whereas at  $-3^{\circ}\text{C}$  the germinating power is soon lost. Conidia are thus adequately protected against harm from low night temperatures.

#### c) Germination following temperature shocks

Marked fluctuations of temperature are said to have a stimulating effect on the propagation of certain species of Erysiphaceae (Salmon, 1901; Longrée, 1939; Zillig, 1937; Yossifovitch, 1923). These authors, however, do not give definite proof that gemination of conidia is stimulated by temperature shocks. In the following tests, the conidia were, therefore, subjected to abrupt changes of temperature.

The values given in Table 7 have already shown that brief exposure to high temperatures does not stimulate germination of *U. necator*. The germination figures obtained for exposure of conidia to cold treatment for periods of between 4 and 24 hours at  $+3^{\circ}\text{C}$  and  $-4^{\circ}\text{C}$  are given in Table 9.

Table 9: Average number of conidia expressed in % that germinated in optimum conditions following cold treatment at temperatures of  $-4^{\circ}\text{C}$  and  $+3^{\circ}\text{C}$ .

| Period of treatment:           | 4    | 8    | 16   | 24   | hours |
|--------------------------------|------|------|------|------|-------|
| Temperature                    |      |      |      |      | Check |
| $-4^{\circ}\text{C}$ $\bar{x}$ | 71.6 | 69.8 | 66.1 |      | 72.4  |
| $s_x$                          | 3.4  | 4.3  | 5.5  |      | 2.7   |
| $+3^{\circ}\text{C}$ $\bar{x}$ |      |      |      | 81.4 | 79.3  |
| $s_x$                          |      |      |      | 2.8  | 2.7   |



It is perceived that this treatment did not stimulate germination, either. Also when separated infected leaves were subjected to cold treatment, the conidia that were sampled afterwards showed no reaction in their germination. The stimulation of parasites observed in the field as the result of fluctuations of temperature cannot, therefore, be explained as being due to a stimulation of conidial germination.

#### *d) Influence of temperature on rate of germination*

The germinating power of conidia is characterized not only by certain percentages of germination but also by the time in which these are attained. This rate of germination may be of great importance to a successful infection. It was determined by the author at 10, 16, 20, 25, 27, 30 and 32°C, the percentages of germination being counted repeatedly at certain intervals of time. The results are illustrated in Fig. 3. The flat run of the curve clearly shows the slowing down of germination at temperatures below and above the optimum range; within this range the curves are close together, the differences being slight.

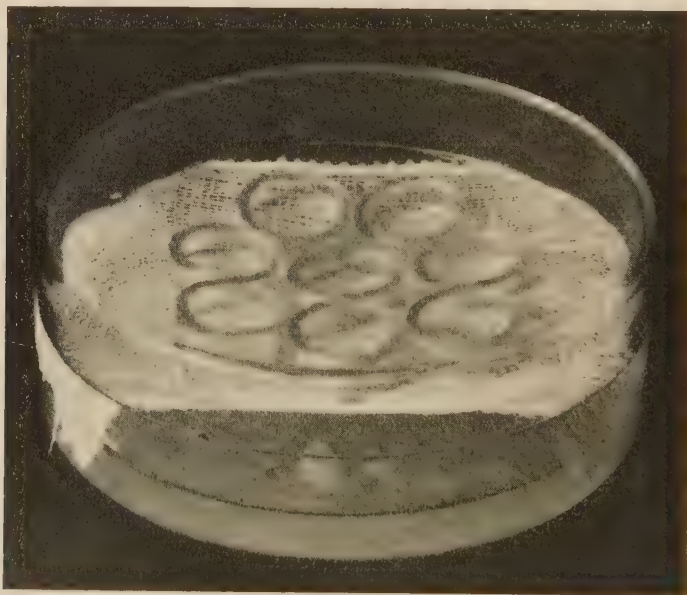


Fig. 4: Production of constant moisture conditions by using salt pulps

### 2. Influence of relative humidity on germination at constant temperature

Erysiphaceae, in contrast to most other fungi (Doran, 1922), are not dependent upon a supply of liquid water during conidial germination; this was already observed by de Bary (1884). The requirements of moisture vary most greatly, however, among the different species (Yarwood, 1936; Lon-

grée, 1939; Stoll, 1941; Clayton, 1942). The germination of *U. necator* conidia is in fact inhibited by liquid water. On the other hand, the high germination percentages which the author recorded on collodion membranes led to the assumption that relative humidity exerts a strong influence. Yossifovitch, however, did not establish a definite dependence of germination on relative humidity, although here the methodical difficulties must not be overlooked. Therefore, it was decided to investigate whether, with improved constancy of the test conditions, conidial germination definitely reacts to relative humidity.

The tests were carried out in glass thermostats at 25° C. The relative humidity was set at constant values by means of salt pulps (Janisch, 1933) in sealed Petri dishes. Collodion membranes mounted on empty glass rings were used as germinating substrate. Fig. 5 illustrates the test method. Two test series, in which the membranes were either mounted on water or mounted dry in moist chambers, were carried out as checks. After 48 hours, the conidia had dried up in all the tests with the exception of the first check series. Later germinations were thus precluded. The results are given in Table 10 (n = no. of test units — glass rings — each containing approximately 450 counted conidia). The germination numbers registered at 92 and 93 % relative humidity were combined.

Table 10: Average germination in % at varying relative humidity and a temperature of 25° C.

| Relative humidity in %     | Germination $\bar{x}$ | $s_{\bar{x}}$ | n  |
|----------------------------|-----------------------|---------------|----|
| Check 1: membrane on water | 81.4                  | 1.3           | 47 |
| Check 2: in moist chamber  | 60.6                  | 1.4           | 62 |
| 96                         | 41.3                  | 2.3           | 16 |
| 92 and 93                  | 30.1                  | 2.4           | 28 |
| 83                         | 32.9                  | 2.8           | 15 |
| 75                         | 36.7                  | 3.3           | 13 |
| 63                         | 29.3                  | 2.5           | 24 |
| 56 (20° C)                 | 18.5                  | 2.4           | 15 |
| 51                         | 0                     | 0             | 30 |

A value which was recorded due to a technical error, at 20° C instead of 25° C, corresponding to 56 instead of 51 % r. h., fitted in with the other values and is, therefore, included in the results. The percentage of germination, therefore, decreases most between 100 and 92 % r. h. The slight rise of the relative humidity in a moist chamber caused an increase in germination from 41.3 to 60.6 %, as compared with 96 % r. h. It is obvious to attribute the high percentages of germination on membranes mounted over water, to a further improvement of the constancy of relative humidity. It is noticeable that the value 36.7 at 75 %

r. h. is significantly higher statistically than the values at 92/93% and 63% r. h., respectively; this point will still have to be dealt with. As compared with the data of Yossifovitch, it was possible to define the moisture requirements of *U. necator* much more accurately.

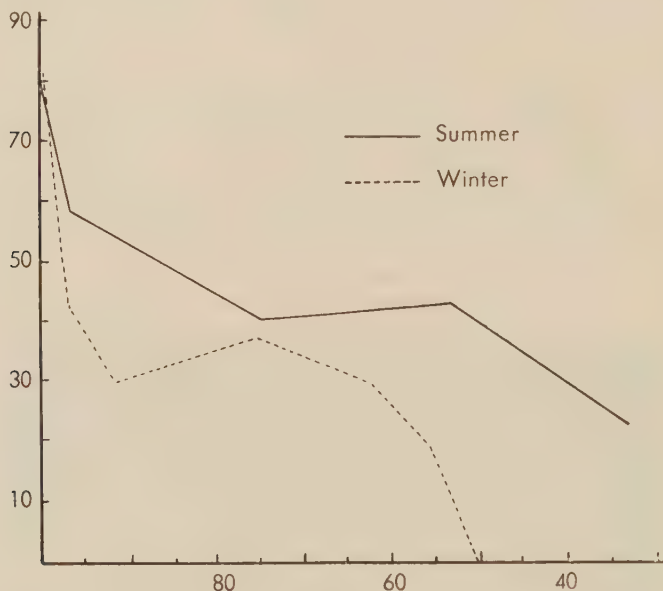


Fig. 5: Reaction of germination at decreasing humidity in different seasons.  
 Abscissa: Relative humidity in %  
 Ordinate: Conidial germination in %

### 3. Influence of varying relative humidity and temperature on germination

Fluctuations of temperature are accompanied by a rapid change of relative humidity in natural conditions, a fact which gave rise to carrying out a study of the reaction of conidial germination to the relative humidity at varying temperatures. The same method was used as described above, with the exception that the Petri dishes containing the salt pulps, were placed in exsiccators filled with similar salt pulps. Five stages of relative humidity (100, 96, 75, 55, 33% r. h) and six temperatures (32, 30, 27, 22, 15, 10°C) were selected. The results are given in Table 11.

The statistical significance ( $p > 5\%$ ) of the respective difference between the total means for temperature and relative humidity, respectively, is marked by the sign  $<$  or  $>$ ; the sign  $\sim$  is understood to mean that the difference is not significant. The analysis of variation method was applied for the evaluation. Decreasing relative humidity again led to a marked drop in germination whereas the temperature, over a wide range, had no appreciable effect on ger-

Table 11: Average germination in % at varying relative humidity and temperature

| Temperature   | Check  | Relative humidity in % |        |      |      |               |
|---------------|--------|------------------------|--------|------|------|---------------|
| ° C           | 100    | 96                     | 75     | 55   | 33   | Total average |
| 32            | 12.9   | 0                      | 0      | 0    | 0    | 2.6           |
| 30            | 50.3   | 50.6                   | 10.3   | 25.2 | 11.6 | 29.6 <        |
| 27            | 86.2   | 59.0                   | 29.1   | 42.6 | 22.7 | 47.9 <        |
| 22            | 77.4   | 65.8                   | 52.4   | 47.3 | 26.3 | 53.8 <        |
| 15            | 74.4   | 52.6                   | 40.3   | 37.7 | 20.4 | 45.1 >        |
| 10            | 91.4   | 76.7                   | 37.6   | 35.2 | 3.3  | 48.8 ~        |
| Total average | 75.9 > | 60.9 >                 | 33.9 ~ | 37.2 | 16.9 |               |

mination. A definite dependence of the temperature effect upon the various stages of relative humidity, and vice-versa, was not apparent, with one exception which is at 10° C and 33 % r. h. At these values the two inhibiting factors intensified each other's influence, leading to an unexpectedly low germination of 3.3 %. Another noticeable feature is the marked depression of germination at 75 % r. h. and at 30 and 27° C as compared with the values at 55 % r. h., which is fully contradictory to the increase in Table 10. These conditions were, therefore, examined in a separate test at 75 and 47—56 % r. h. and at 30 and 27° C. The salt solutions used were changed here in order to preclude specific influences. The results are given in Table 12.

Table 12: Average germination in % at 47—56 and 75 % r. h. and at 27° and 30° C.

| Test series   | Temperature<br>° C | Relative humidity % |       |
|---------------|--------------------|---------------------|-------|
|               |                    | 75                  | 47—56 |
| 1             | 30                 | 10.3                | 25.2  |
| 2             | 30                 | 6.3                 | 18.5  |
| 3             | 30                 | 13.5                | 19.7  |
| 4             | 30                 | 1.0                 | 19.8  |
| 5             | 27                 | 17.7                | 43.1  |
| 6             | 27                 | 29.2                | 42.6  |
| Total average |                    | 12.9                | 27.3  |

At a relative humidity of 75 %, there was a significant ( $p < 1\%$ ) decrease in germination averaging 14.4 %. At the same time, the conidia remained turgescient for a longer period at 75 % r. h. The author then investigated how the conidia react to a brief effect by the different relative humidity stages and



temperatures with subsequent germination over water at 22°C. The temperatures and relative humidity were graded as given in Table 11. The periods of exposure amounted to 8 and 4 hours, respectively. The values obtained at the six temperatures are combined in Table 13 because they did not have detectable influence on germination. The influence of the relative humidity, however, was most noticeable.

Table 13: Average germination in % for 4 and 8 hour exposure to varying degrees of relative humidity, followed by optimum conditions.

|                     | Check<br>(membrane on water) | Relative humidity in %<br>and period of exposure |           |           |           |
|---------------------|------------------------------|--------------------------------------------------|-----------|-----------|-----------|
|                     |                              | 96<br>8 h                                        | 75<br>8 h | 55<br>8 h | 33<br>4 h |
| Average germination | 81.4                         | 66.9 >                                           | 58.7 >    | 36.4 ~    | 45.1      |

The statistical significances of the differences for the means are again marked by signs. A comparison with the values given in Table 11 shows that the germination figures registered following brief exposure to low relative humidity were nearly always higher than following lengthy periods of persistent exposure, a finding which gains importance especially for the lowest r.h. (33 %), because it appreciably increases the chances of conidia surviving outdoors. The above-mentioned decrease in germination at 75 % r.h. was not observed here. The conidia remained turgid for a longer period at this relative humidity, as already stated, and are able to germinate afterwards in favourable conditions.

There are certain differences between the germination numbers recorded at varying relative humidity as given in Tables 10 and 11; these are shown in Fig. 6. The values in Table 10 were obtained in winter, and those in Table 11 were recorded in summer. The curve plotted for the winter values is much steeper than that plotted for the summer values. Whereas no further germination took place at 51 % r.h. in winter, a considerable percentage of conidia germinated at 33 % r.h. in summer. The extent of the difference leads to the assumption that a seasonal influence is responsible for the varying germination of the conidia. In the centre of their run, both curves feature a reversal of the germination figures which has already been pointed out, in other words a certain renewed increase. This is more marked in winter when it occurs between 91 and 75 % r.h.; in summer it is between 75 and 55 % r.h. This phenomenon was assumed to attach certain epidemiological importance in that the reduced germination in this range accompanied by good preservation of the conidia brought about a stimulated propagation of the parasites in the field.

### V. Incidence of *U. necator* in greenhouses

Observations on the infection of grape vine plants in greenhouses by *U. necator*, extending over a period of three years, revealed considerable differences in the intensity of infection and in the symptoms of infection within the

course of a year. On the basis of these findings, it was possible to divide the year into four sections. These are outlined below because they permit certain generally applicable conclusions to be drawn.

#### 1st section: December to March.

Plant growth: In December at average temperatures of 20 to 26° C, strongly sprouting plants feature soft stems full of water with long internodes and small, tender leaves lacking chlorophyll. Intensity of infection: severe. Symptoms of infection: unchecked spread of fungus over stem and leaves. Mealy deposits of dry conidia on older leaves. Young leaves often deformed. Severest damage to plants with signs of dying shoot tips and leaves.

#### 2nd section: April to June

Plant growth: Plants that have sprouted in March and are in vigorous growth, feature tender yet firmer stems with shorter internodes and large, tender, dark-green leaves. Intensity of infection: moderate. Shoot tip free of infection, 4th to 6th leaves most severely infected. Symptoms of infection: Clearly defined, rather inconspicuous and relatively small infection sites only on the leaves, no harm to the plants.

#### 3rd section: July to September

Plant growth: Plants that sprouted in March stop growing during July. Also those which sprouted in April or May have less vigorous growth. Stems and leaves are sturdier and contain less water. Intensity of infection: moderate to weak, only isolated plants severely infected. Symptoms of infection: plants that sprouted in March have stopped growing, completely covered by fungus, and have typical mealy deposits on the leaves. Plants that sprouted later and which are less seriously harmed, show symptoms on the leaves characteristic of the 2nd section, and frequently the shoot tips are also infected. Apparent stoppage of fructification on the older leaves because the conidial chains mostly have 2—3 dry terminal conidia. On sturdy plants, a symptom appears which was described by Salmon (1901) and Neger (1923) as a "sub-infection" — slightly sunken, bright spots, diameter of 1 to 2 mm, usually accompanied by one or several necrotic parts, mycelium residues and one or several stunted conidiophores. This symptom indicates an apparently high resistance of the host.

#### 4th section: October and November

Plant growth: Progressive lignification of the mature plants in autumn. Plants pruned in summer produce fewer new shoots than in spring. Intensity of infection: slight to moderate, isolated leaves severely infected on old plants. Symptoms of infection: before leaf shedding, there is often a serious propagation of the parasite and marked fructification accompanied by rapidly drying conidia on leaves that have already been infected for lengthy periods. New shoots show same symptoms of infection as in spring.

A change in the disposition of the host due to lack of light in winter may be put down as being responsible for the seasonal differences in the severity of infection. Furthermore, the similar influence of other factors, without any marked change in the overall habitus of the plants, should be considered, as demonstrated by the following test. Batches of 30 infected plants which sprouted

in April, were placed in May in two greenhouse cabins. The one was protected against direct sunlight, and against night cold by means of a special heating system (north cabin), whereas the other was exposed to considerable fluctuations of temperature (south cabin). The respective means for the daily minimum and maximum temperature and relative humidity in both cabins, are given in Table 14.

Table 14: Mean minimum and maximum temperature and relative humidity from May 4 to June 24, 1953, in two greenhouse cabins.

|                 | North cabin |      | South cabin |      |
|-----------------|-------------|------|-------------|------|
|                 | min.        | max. | min.        | max. |
| Temperature °C  | 20.4        | 28.4 | 15.5        | 27.8 |
| Rel. humidity % | 57          | 89   | 55          | 91   |

With regard to the absolute maxima, temperatures above 34°C — the germination maximum for the parasite — were measured only on seven days and only for brief periods also in the south cabin, so that harm to the conidia was not to be anticipated.

The infection in the north cabin was of uniform severity; in the south cabin it was only slight. Here the infection sites were clearly defined, and the plants appeared to be somewhat stronger. Exchanged plants became adapted to the new conditions within about ten days, with respect to growth and infections. In June, sub-infections appeared on the plants in the south cabin; the state of infection in the north cabin remained unchanged. The spring infections disappeared on the plants growing near the south wall (exposed to strong sunshine) of the south cabin, so that in July the plants were practically free of primary infection, and only showed signs of the above-mentioned sub-infections.

An infection test was carried out at extremely high temperatures and low relative humidity in order to establish whether, in view of these results, it is possible to prevent infection of young plants cultivated in moderate climatic conditions. Two batches of four plants each, grown under such conditions, were placed in the north cabin and in the additionally heated south cabin, respectively. The climatic data are given in Table 15.

Before the start of the test, all the plants were placed for a period of 8 hours among severely infected plants in order to ensure a high rate of conidial colonization. After three days, both groups of plants were weakly infected; the infection had worsened most appreciably after ten days although it was evident that the parasite had developed better in the north cabin than in the south cabin. Here, the plants were apparently harmed somewhat due to the high temperatures that prevailed.

It is to be concluded from both tests that with a disposed host, infection can occur and the parasite can continue its development despite unfavourable temperature and relative humidity. In the unheated and partly almost infection-free south cabin of the first test, the temperature and relative humidity

Table 15: Climatic data for the south greenhouse cabin provided with additional heating, June 27 to July 6, 1953.

| Date   | Temp. °C |      | no. of hrs.<br>above 30 °C | Rel. humidity % |      | no. of hrs.<br>under 50 % |
|--------|----------|------|----------------------------|-----------------|------|---------------------------|
|        | min.     | max. |                            | min.            | max. |                           |
| 27. 6. | 18       | 32   | 2                          | —               | —    | —                         |
| 28. 6. | 22       | 35   | 10                         | 43              | 85   | 7                         |
| 29. 6. | 26       | 45   | 7                          | 33              | 82   | 3                         |
| 30. 6. | 23       | 36   | 10                         | 40              | 80   | 3                         |
| 1. 7.  | 21       | 34   | 7                          | 42              | 92   | 4                         |
| 2. 7.  | —        | —    | —                          | —               | —    | —                         |
| 3. 7.  | 19       | 30   | 0                          | 55              | 97   | 0                         |
| 4. 7.  | 22       | 32   | 4                          | 55              | 76   | 0                         |
| 5. 7.  | 21       | 33   | 7                          | 43              | 74   | 7                         |
| 6. 7.  | 21       | 37   | 12                         | 38              | 60   | 12                        |

were far more favourable for conidial germination than in the same, additionally heated south cabin of the second test when infection was most severe. The resistance that appeared in the first case can, therefore, not be attributed so much to harm of the parasite as to a change in the disposition of the host under the influence of environmental factors.

## VI. Discussion of Results

Tests on conidial germination under different environmental conditions revealed, in contrast to the results of Yossifovitch, that there is a definite dependence of germination percentage on relative humidity. As the requirements for a high degree of moisture on the leaf surface are usually satisfied, high relative humidity is important especially in view of the anemochor propagation of the conidia. Even at a relative humidity which does not allow some of the conidia to germinate, the germinating power of the conidia is nevertheless maintained for several hours. Conidia can in fact survive extremely dry conditions for a brief period.

The temperature requirements for germination of conidia are not closely limited. At temperatures of between 15 and 27 °C, there are no differences in the percentage of germination; merely slight differences in the rate of germination are recorded in this temperature range. No further germination is observed at 4.5 and 34 °C, although even at these temperatures the germinating power is still maintained for a certain period. This means that the conidia generally adapt themselves very well even to extreme climatic conditions.

The germinating power is partly determined already during the formation of conidia. It was observed to undergo a marked decrease in winter when there is poor light, this apparently acting on the parasites via the host, as shown by



the use of additional lighting. The germinating power decreased also in high summer.

The observations in the greenhouse revealed that there is a definite relationship between mildew infection of grape vines and the disposition of the latter. Young tissue was found to be very susceptible. Environmental conditions which accelerate maturity also accelerated the development of resistance. The incidence of so-called sub-infections as maturity progresses, and mass reproduction on dead plant parts in autumn indicate active resistance brought about physiologically. The importance which the disposition of the plant attaches with respect to the activity of the parasite makes it understandable why the causes of mass incidence of the parasite in the field are not easy to establish. Differences in location, weather and climatic conditions may be equally influential here. Isolated observations should, therefore, by no means be generalized. (Sajo, 1901; Sorauer, 1886). Nevertheless, it can be expected that moist summer conditions with little sunshine will lead to disposition of the host that is favourable to the development of the parasite, and thus to the outbreak of an epidemic (Müller, 1918; Arnaud, 1932; Bremer et al, 1952; Zillig, 1937, 1940).

The fact that an infection occasionally does not succeed in greenhouses may also be attributed to the varying susceptibility of the grape vines, although there should not be any difficulty in bringing about a severe infection of greenhouse grape vines for test purposes at least in spring. Schaffnit and Volk (1930) obtained good infection results even in early July; Husfeld and Scherz (1934), on the other hand, give no definite dates. Only Seeliger (1925) obtained good infections every time irrespective of the season although he worked with cut-off shoot terminals which can be infected more easily — just like removed leaves — than intact plants. Teschner (1953) demonstrated that seedlings also readily lend themselves to infection for test purposes.

## VII. Summary

I. Germination tests were carried out in vitro with conidia of *Uncinula necator* (Schwein.) Burr. to provide information about the dependence of the germination process on ambient factors.

1. Collodion membranes floating on water proved to be very suitable germinating substrates.
2. Coverage of conidia with water prevented germination.
3. A drop in relative humidity from 100 to 96 % brought about a considerable decrease of the germination percentage. At a relative humidity of between 75 and 55 % about half the conidia germinated, that is those capable of germinating, whereas only a fifth germinated at 34 %. At 96 % r.h., all the conidia had died after 24 hours. The germinating power was partly maintained following brief exposure to low relative humidity, and was very good at 75 % r.h.
4. Light (daylight and electric light) doubled the germination percentage as compared with darkness. The stimulating effect on germination became apparent after only one hour of light.

5. The temperature range of 15 to 27° C is the most favourable for germination. No further germination was observed at 4.5 and 32° C. The germinating power was fully maintained for up to 14 days, however, at 4° C and optimum relative humidity, but only for up to 8 hours at 34° C. Harm increased rapidly above 34° C. On the other hand, temperatures below freezing point were tolerated for several days without any loss of germinating power.
- II. Tests were also conducted to establish whether effects exerted during the formation of conidia have any influence later on germination.
1. Differences due to age did not appear during the germination of turgescient conidia.
  2. The time of the day when conidia were sampled and the weather that prevailed during the development of conidia had no influence on germination.
  3. The number of winter conidia that germinated was only half as large as that recorded for spring conidia. The differences were balanced by giving the plants additional light in winter. In high summer when the susceptibility of the plants was not so great, the germinating power of the conidia decreased.
- III. Observations of infection on greenhouse grape vines extending over the whole year showed what bearing the disposition of the host has on the severity of infection. Tender winter plants were the most severely infected; mature, high-summer plants were extremely resistant.

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